S. HRG. 112–960

NUTRIENT POLLUTION: AN OVERVIEW OF NUTRIENT REDUCTION APPROACHES

HEARING

BEFORE THE

SUBCOMMITTEE ON WATER AND WILDLIFE

OF THE

COMMITTEE ON
ENVIRONMENT AND PUBLIC WORKS
UNITED STATES SENATE

ONE HUNDRED TWELFTH CONGRESS

FIRST SESSION

OCTOBER 4, 2011

Printed for the use of the Senate Committee on Environment and Public Works

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COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS

ONE HUNDRED TWELFTH CONGRESS
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SUBCOMMITTEE ON WATER AND WILDLIFE

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NUTRIENT POLLUTION: AN OVERVIEW OF NUTRIENT REDUCTION APPROACHES

TUESDAY, OCTOBER 4, 2011

U.S. SENATE
COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS,
Subcommittee on Water and Wildlife
Washington, DC.

The subcommittee met, pursuant to notice, at 2:30 p.m. in room 406, Dirksen Senate Office Building, Hon. L. Benjamin Cardin (chairman of the subcommittee) presiding.

Present: Senators Cardin, Sessions, Whitehouse, Inhofe, Boozman.

OPENING STATEMENT OF HON. BENJAMIN L. CARDIN, U.S. SENATOR FROM THE STATE OF MARYLAND

Senator CARDIN. Good afternoon, everyone. The Subcommittee on Water and Wildlife will come to order.

Our hearing today deals with Nutrient Pollution, an Overview of Nutrient Reduction Approaches. I want to thank all of our witnesses that are here. Nutrient pollution from nitrogen and phosphorus has consistently ranked as one of the top causes of degradation of some of U.S. waters for more than a decade. It results in significant water quality problems, including harmful algae blooms and declines in wildlife and wildlife habitat. These in turn harm the fishing, recreation and service industries that are dependent on the health of those waterways.

The goal of today's hearing is to document how nutrient pollution is a national problem. We will hear about its causes and impacts. We will also hear about effective approaches to reduce and control nutrient pollution.

We invited two panels of witnesses to today's hearing. They will report on how the Federal, State and local representatives have developed a variety of solutions tailored to meet the needs of individual bodies of water. They will also relate how the low oxygen levels in our Nation's water persist despite local efforts.

On our first panel, representatives of the Environmental Protection Agency, the Department of Agriculture and U.S. Geological Survey will present scientific data on the impacts of nutrient pollution. They will speak to ongoing collaborative efforts between the agencies and local governments to stem the tide of pollutants.

On the second panel we will hear from stakeholders about the first-hand impacts of nutrient pollution on such disparate activities as farming and outdoor recreation. We will also hear about innovative technologies and practices that are succeeding in reducing nutrient pollution in cost-effective ways.

Nutrient pollution is bad for our Nation's coastal waters and lakes. Excesses of nitrogen and phosphorus cause the concentration of dissolved oxygen in water to decrease to a level that can no longer support living aquatic organisms, creating vast dead zones in our Nation's water. In the northern Gulf of Mexico this year, dead zones were in excess of 6,500 square miles, larger than the size of New Jersey. In the Chesapeake Bay this year, dead zones covered over one-third of the Bay. And waters outside the dead zone are threatened as well.

A recent study found that in total, over 80 percent of the Chesapeake and its tributaries are either low oxygen or no oxygen as a result of nutrient pollution. Without sufficient oxygen levels, plants and marine life suffocate, leaving far fewer fish and shellfish for our Nation's commercial and recreational fishermen. Deoxynized water also feeds algae blooms, making water unsuitable for both industry and recreation, including public health risks with the quality of our drinking water.

This problem is not new. Forty years ago, we were warned that submerged grasses in the Bay were dying because of excess nitrogen and pollution. The grass beds provide shelter to oysters and waterfowl. Today, due to a combination of factors, including nutrient pollution, the Bay's native oyster population is small fraction of what it once was.

As a result, the oyster harvest value has declined 88 percent in the past three decades. Further, in the past two decades, the number of working oystermen in the Bay has decreased 92 percent. Oystering once supported over 6,000 Maryland families. Today, only 500 oystermen remain. This is just one example of not only the environmental but also the economic devastation that nutrient pollution can cause.

The Clean Water Act has helped tremendously with addressing pollution discharges from point sources, such as factories. However, by every scientific measure, the ecological health of the Chesapeake Bay is still poor. Its persistent ill health stems from the continued flow of pollutants including nutrients from non-point sources.

I want to repeat what I said before. Despite the protection of the Clean Water Act, one-third of the Chesapeake Bay was unable to support aquatic life this year. The Bay and its tributaries have been harmed by too much runoff from farmlands, too much urban and suburban development, and too many impervious surfaces.

Unfortunately, the Bay is not unique in suffering this harm. Water bodies across the Country are dealing with similar threats from nutrient runoff. In today's hearing, we will be examining the best methods for addressing this pervasive problem.

The Water and Wildlife Subcommittee has a responsibility to ensure that the Nation's water quality laws are actually working and producing results. This is an ongoing debate about the appropriateness of the Federal role in nutrient reduction. Some argue that policing this runoff is an issue best left to the States. Well, in Maryland the State has spent $100 million a year over the past decade on nutrient reduction and improving the Bay. In spite of the State's concentrated effort, the health of the Bay is still diminished.

The key to the Bay's restoration lies in recognizing that it is merely the most obvious part of a much larger watershed. The Chesapeake Bay's watershed encompasses six States and the District of Columbia. Maryland's efforts alone cannot block runoff that originates across its borders. We must address the pollution in the Chesapeake Bay by dealing with all the pollution in the entire watershed. This is a watershed-wide problem and the only real remedies lie in the watershed-wide solutions. A coordinated effort is necessary to restore our Nation's treasure.

The same is true with other water bodies across the Country, ranging from the Great Lakes to the Gulf of Mexico, from the Long Island Sound to the San Francisco Bay. Today's hearing will demonstrate that nutrient pollution can be mitigated with collaborative efforts and a coordinated role for Federal agencies.

I want to again thank the witnesses who are joining us today in our effort to understand and reduce the damaging effects of dead zones on our Nation's water.

We will now to turn to the Ranking Republican Member of the Subcommittee, Senator Sessions.

[The prepared statement of Senator Cardin follows:]

STATEMENT OF HON. BENJAMIN L. CARDIN, U.S. SENATOR FROM THE STATE OF MARYLAND

Nutrient pollution from nitrogen and phosphorus has consistently ranked as one of the top causes of degradation in some U.S. waters for more than a decade. It results in significant water quality problems including harmful algal blooms, hypoxia (low oxygen levels), and declines in wildlife and wildlife habitat. These, in turn, harm the fishing, recreation, and service industries that are dependent on the health of those waterways.

The goal of today's hearing is to demonstrate that nutrient pollution is a national problem. We will hear about its causes and impacts. We will also hear about effective approaches to reduce and control nutrient pollution.

We have invited two panels of witnesses to today's hearing. They will report how Federal, state, and local representatives have developed a variety of solutions tailored to meet the needs of individual bodies of water. They will also relay how the low-oxygen levels in our nation's waters persist despite local efforts.

On our first panel, representatives of the Environmental Protection Agency, the Department of Agriculture, and the U.S. Geological Survey will present scientific data on the impacts of nutrient pollution. They will speak to ongoing collaborative efforts between the agencies and local governments to stem the tide of pollutants.

In the second panel, we will hear from stakeholders about the firsthand impacts of nutrient pollution on such disparate activities as farming and outdoor recreation. We will also hear about innovative technologies and practices that are succeeding in reducing nutrient pollution in cost-effective ways.

Nutrient Pollution and Low Dissolved Oxygen:

Nutrient pollution is bad for our nation's coastal waters and lakes. Excesses of nitrogen and phosphorus cause the concentration of dissolved oxygen in water to decrease to a level that can no longer support living aquatic organisms, creating vast "dead zones" in our nation's waters. In the northern Gulf of Mexico, this year's dead zone was 6,765 square miles, larger than the size of New Jersey. In the Chesapeake Bay, this year's dead zone covered over one third of the Bay. And waters outside of that dead zone are threatened as well.

A recent study found that in total over 80 percent of the Chesapeake and its tributaries are either low-oxygen or no oxygen as a result of nutrient pollution.

Without sufficient oxygen levels, plants and marine life suffocate, leaving far fewer fish and shellfish for our nation's commercial and recreational fishermen. Deoxygenated water also feeds vast and odorous algal blooms, making water unsuitable for both industry and recreation.

This problem is not new, and its effects are not limited to wildlife.

Forty years ago, we were warned that submerged grasses in the Bay were dying because of excess nutrients and pollution. The grass beds provided shelter to oysters and waterfowl. Today, due to a combination of factors including nutrient pollution, the Bay's native oyster population is a small fraction of what it once was. As a result, the oyster harvest value has declined 88 percent in the last three decades.

Further, in the past two decades, the number of working oystermen on the bay has decreased 92 percent. Oystering once supported over 6,000 Maryland families. Today only 500 oystermen remain. This is just one example of not only the environmental, but also the economic devastation that nutrient pollution can cause.

The Clean Water Act has helped tremendously with addressing pollution discharges from point sources, such as factories. However, by every scientific measure, the ecological health of the Chesapeake is still poor. Its persistent ill health stems from the continued flow of pollutants, including nutrients, from non-point sources.

I want to repeat what I said before: Despite the protections of the Clean Water Act, one third of the Chesapeake was unable to support aquatic life this year.

The Bay and its tributaries have been harmed from too much runoff from farm lands, too much urban and suburban development, and too many impervious surfaces. Unfortunately, the Bay is not unique in suffering this harm. Water bodies across the country are dealing with similar threats from nutrient runoff. In today's hearing, we will be examining the best methods for addressing this pervasive problem.

Making Sure Our Laws Work:

The Water and Wildlife Subcommittee has a duty to ensure that the nation's water quality laws are actually working and producing results. There is an ongoing debate about the appropriateness of the Federal role in nutrient reduction. Some argue that policing this runoff is an issue best left up to the states. Well, in Maryland, the State has spent $100 million dollars a year over the past decade on nutrient reduction and improving the Bay. In spite of the state's concentrated efforts, the health of the Bay is still diminished.

The key to the Bay's restoration lies in recognizing that it is merely the most obvious part of a much larger watershed. The Chesapeake Bay's watershed encompasses six states and the District of Columbia. Maryland's efforts alone cannot block runoff that originates across its borders. We must address the pollution in the Chesapeake by dealing with all the pollution in the entire watershed. This is a watershed-wide problem and the only real remedy lies in watershed-wide solutions. A coordinated effort is necessary to restore this national treasure.

The same is true of other water bodies across the country, ranging from the Great Lakes to the Gulf of Mexico, and from Long Island Sound to San Francisco Bay.

Today's hearing will demonstrate that nutrient pollution can be mitigated with collaborative efforts and a coordinating role for Federal agencies. I want to thank our witnesses for joining us today to assist in our efforts to understand and reduce the damaging effects of dead zones in our nation's waters.

OPENING STATEMENT OF HON. JEFF SESSIONS, U.S. SENATOR FROM THE STATE OF ALABAMA

Senator SESSIONS. Thank you, Chairman Cardin. You have the great historic Chesapeake Bay, and we have the historic Mobile Bay. I have been involved over the years with those who have committed great effort and leadership to improving the quality of Mobile Bay.

And I have concluded that nutrient and sediment runoff is probably the greatest threat to our bays. We have a number of chemical companies and industrial plants up and down the river. But over the years, those have been improved dramatically, very little runoff in terms of chemical pollution into our waters.

But sediment, nutrients from fertilizers and all do present problems. There is no doubt about it. And it is a good thing for us to talk about. Nutrient pollution, as you noted, contributes to dead zones in the Gulf of Mexico, which is around 3,000 to 9,000 square miles, which is a large area. It represents, however, I would note, about 1 percent of the Gulf of Mexico, but it is a dead zone that I think can be traced to nutrient runoff.

In Mobile Bay, over the centuries, we have had jubilees, when crab, shrimp, fish come up on the shore. They have done this since the founding of the area 300 years ago. They have been documented. So some of this is natural, where the oxygen level is reduced and the fish have to move away from it. But we know that many things that happen today are exacerbating that.

So the question, I do think, this afternoon is what should the Federal Government do and what role should they play in this problem. The House Subcommittee on Water Resources held a hearing in June. Testimony at that hearing showed that nutrient pollution cannot be remedied through a national numeric water quality standard, a uniform national standard would not be effective. Whether nutrient levels are helpful or harmful to water quality, in some cases, they could be helpful, water depth, flow rates, temperatures, sunlight and other site-specific factors determine what are the danger areas. The sources of nutrient pollution also differ from region to region.

So I do think it is fair to say a one size fits all, a national regulation of uniform approach is not the right way to go forward. I do believe we should rely primarily on States to develop water quality standards for nutrients in a manner that they believe effective. Multiple States can work together collaboratively. Voluntary efforts by the agricultural community and landowners and industries can also be helpful, and indeed, are being helpful. I know in Mobile, they have drawn up an entire map of the Bay and where the runoffs are occurring and progress has been made over the years toward reducing that.

But I am concerned, the approach EPA is currently taking in places like Florida, instead of the cooperative federalism, EPA does seem to be utilizing coercive federalism. So I believe that is an unhealthy trend. I question whether EPA has the resources to develop standards nationwide, national standards. And I would like to offer for the record at this time written comments submitted by stakeholders in my State, from the Alabama Department of Environmental Management who works on this, the Alabama Department of Agriculture, John McMillan, Commissioner, and the Farmers Federation of Alabama, ALFA, and their remarks.

Senator CARDIN. Without objection, all those statements will be included in the record.

[The referenced information follows:]

Lance R. LeFleur
Director

ADEM

Robert J. Bentley
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September 30, 2011

The Honorable Jeff Sessions
Ranking Member, Subcommittee on Water & Wildlife
United States Senate
326 Senate Russell Building
Washington DC 20510

RE: Nutrient Pollution: An Overview of Nutrient Reduction Approaches

Dear Senator Sessions:

The Alabama Department of Environmental Management wishes to thank the subcommittee members for this opportunity to offer its thoughts on nutrient reduction approaches.

The Problem

Nutrients serve a very important role in our environment. They provide the essential building blocks necessary for growth and development of healthy aquatic ecosystems. However, if not properly managed, nutrients in excessive amounts can have detrimental effects on human health and the environment, creating such water quality problems as excessive growth of macrophytes and phytoplankton, harmful algal blooms, dissolved oxygen depletion, and an imbalance of flora and fauna. Based on water quality reports to Congress, nutrient over-enrichment is identified as one of the leading causes of designated use impairments to surface waters throughout the Nation.

History of Addressing the Problem

In 1998, the United States Environmental Protection Agency (EPA) published a national strategy to address nitrogen and phosphorus pollution and states were given the responsibility of developing and implementing numeric nutrient criteria to protect designated uses in the Nation's surface waters. Since that time, the states and EPA have invested enormous resources in efforts to develop scientifically sound criteria while continuing to reduce nitrogen and phosphorus loading to waters already impaired by over-enrichment. The development of numeric nitrogen and phosphorus criteria using available science has not been an easy task because of the many confounding factors that affect how natural aquatic systems respond to nitrogen and phosphorus inputs. EPA's 1998 strategy recognized the complexity of this issue by stating that one set of criteria will not work for all waters or waterbody types. Identification of the level at which nitrogen or phosphorus or both nutrients result in a detrimental response in an aquatic ecosystem is the Holy Grail that researchers seek and, in some notable cases, have been successful in finding. However, for the vast majority of states this causal link between nitrogen and phosphorus enrichment and impairment of the designated use continues to be elusive. Establishing numeric nitrogen and phosphorus criteria for surface waters and using those numeric concentrations to determine use impairment fails to recognize the important link between nutrients, the response to nutrients, and protection of the designated use.

EPA's Approach to the Problem

For this reason, many states, including Alabama, are advocating an approach that would set numeric criteria for nitrogen or phosphorus or both for waterbodies using the best available scientific information but would allow the determination of use impairment to be made on the basis of impacts to aquatic communities. EPA's policy on independent applicability states that exceedance of numeric criteria represents impairment of the designated use regardless of the response in the biological community. This approach seems unreasonable for pollutants such as nitrogen and phosphorus which are not toxic and which elicit such a wide range of responses in natural systems.

Alabama's Approach to the Problem

Alabama's nutrient criteria development approach has focused on addressing those waterbodies where available data could be used to establish a response threshold as the basis for establishing numeric criteria. In the case of Alabama's large reservoirs, this response has been the green pigment, known as chlorophyll *a*, produced by microscopic plants growing in the water column. To date, Alabama has successfully established chlorophyll *a* criteria for 37 of its 41 large reservoirs. The State believes that the use of a response variable only approach for reservoirs is an effective way to address the issue of nutrient over-enrichment in this waterbody type but recognizes that when the chlorophyll *a* criterion is exceeded, reductions in either nitrogen, phosphorus, or both may be necessary. In flowing waters, the complexity of the relationship between nitrogen and phosphorus concentrations and the detrimental response is much greater and more site-specific and the criteria development process must allow for protection of downstream uses or uses in downstream states. Alabama is currently involved in several efforts to understand nutrient–response relationships in flowing streams, rivers and estuaries and expects to move forward with numeric nutrient criteria development once these studies are completed.

Impacts of 319 Program

Nutrient reduction efforts in Alabama, and in most other states, began long before EPA released the 1998 National Nutrient Strategy. Reduction in nutrient loading to state waters has been achieved through both voluntary and regulatory approaches. Congressional funding of Clean Water Act Section 319 programs in states has resulted in the installation of thousands of agricultural best management practices to control runoff of nitrogen and phosphorus from agricultural lands. This voluntary program, administered by states, provides cost-share funds to farmers who install practices that restore and protect water quality. Despite the success of this program, nonpoint source runoff continues to be a major source of nutrients in our waters. In a time of reducing budgets, this program must be maintained at a level that supports this vital stakeholder-driven effort. Funding for Section 319 programs is helping to protect Alabama's valuable water resources from the Flint Creek watershed in the Tennessee Valley to the North River watershed and its public water supply near Tuscaloosa to the Hurricane Creek watershed in the wiregrass area of south Alabama.

Water Quality-Based vs Technology-Based Effluent Limits Guidelines

Shortly after the passage of the Clean Water Act in 1972, EPA began developing effluent guidelines for municipal and industrial wastewater treatment facilities. These EPA effluent guideline limits define the minimum treatment levels for various pollutants that would be allowed for various industrial categories and for publicly owned treatment works and are referred to as technology-based effluent guideline limits. Effluent limits necessary to protect the designated uses of receiving streams are referred to as water quality-based effluent limits.

Regulatory approaches to nutrient reduction have been driven primarily by the need to reduce nutrients in impaired waters. States have established water quality-based effluent limits for nitrogen or phosphorus or both for wastewater treatment facilities that discharge to these impaired waters. However, only a handful of states have established technology-based nutrient limits to be applied to municipal or industrial wastewater treatment facilities in the state. Development of effluent guidelines is generally a costly and time-consuming process; however, much of this work has already been accomplished by the wastewater treatment industry to comply with nutrient reductions in impaired waters and nutrient removal technologies and performance standards are becoming widely available.

Amending the "secondary treatment" standards established by EPA in 40CFR 133 at the national level to include minimum treatment levels for nitrogen and phosphorus would level the playing field for municipalities and result in widespread nutrient reductions. In the absence of national effluent guidelines for nitrogen and phosphorus or until states finish the task of establishing numeric nitrogen and/or phosphorus criteria for state waters, effluent limits for nutrients will continue to be determined on a case-by-case basis with a few facilities required to meet very stringent nitrogen or phosphorus limits while others are free from nutrient treatment requirements. In either case, Congressional funding of states through the Clean Water Revolving Loan fund is critical to achieving meaningful nutrient reductions from publicly owned treatment works.

Conclusion

In conclusion, states need time, resources, and flexibility to address nutrient pollution using approaches that rely on the best scientific information available and that apply necessary reductions fairly. Reduction of nutrients from nonpoint sources requires strong partnerships between regulatory agencies, landowners, municipalities, industries, and citizens. Continued support for EPA's Section 319 program is critical to ensuring that the partnerships remain strong and active. States will continue to develop nutrient limits for municipal and industrial treatment facilities where necessary to restore water quality and protect designated uses. In the meantime, however, EPA can be proactive by updating the "secondary treatment" standards to include technology-based effluent guideline limits for nutrients. Regardless, publicly owned treatment works need continued funding through programs such as the Clean Water Revolving Loan fund to achieve nutrient reductions.

Thank you again Mr. Chairman and members of the Committee for this opportunity to provide comments on this important issue.

Sincerely,

Lance R. LeFleur
Director

LRL/LS/ghe

Senator SESSIONS. Director LeFleur, of the Alabama Department of Environmental Management, explains that "Many States, including Alabama, are advocating an approach that would set numeric criteria for nitrogen or phosphorus for water bodies using the best available science but would allow determination of use impairment to be made on the basis of impacts on the aquatic communities.' Jerry Newby at ALFA explains that farmers are increasingly implementing "production practices that allow them to be better environmental stewards.'

So Mr. Chairman, I would ask that the record be left open for 2 weeks to allow members to submit additional material, if that is appropriate.

Senator CARDIN. Without objection, the record of the Committee will be held open for 2 weeks.

Senator SESSIONS. Thank you, Mr. Chairman.

I believe this will be a healthy hearing, and will deal with the tension of a desire to utilize local people who have been working on these estuaries and bays and the Gulf for years, maybe decades, and how they can appropriately work with the national Environmental Protection Agency to improve water quality.

Senator CARDIN. I thank Senator Sessions for your comments.

I now turn to the Ranking Republican Member of the full Committee, Senator Inhofe.

OPENING STATEMENT OF HON. JAMES M. INHOFE, U.S. SENATOR FROM THE STATE OF OKLAHOMA

Senator INHOFE. Thank you, Mr. Chairman, for calling the hearing today. I appreciate the Committee's broad approach to the extremely complex and difficult topic of nutrient pollution.

I also want to thank this Committee for its leadership on a number of important issues like hydraulic fracturing. I want to single you out, Mr. Chairman, for your very kind words you had for our Oklahoma witnesses and your recognition as to how serious this subject is.

I am eager to hear from Ms. Shellie Chard-McClary, who is from Oklahoma, sitting in the third row back there with a smile on her face. That won't last long.

[Laughter.]

Senator INHOFE. Yes, it will. She is a delightful person. She is with our Oklahoma Department of Environmental Quality. She is Division Director of the Water Quality Division.

Then we also have from the States' perspective Richard Budell, who is the Director of the Office of Agricultural Water Policy for Florida. It is very important for us to hear the States' perspective. Because there is a propensity in Washington that all answers and al problems are resolved here. And we know better than that.

Nutrients are different from other water pollutants, because they are not intrinsically toxic. They occur naturally and their presence is essential to healthy water bodies. However, when conditions such as sunlight, temperature, water flow and background water chemistry are right, they can be problematic. I know that we went through this experience in Oklahoma last June. A lot of people are not aware, probably some in this room are not aware of the fact that Oklahoma has the largest, the most miles of freshwater shoreline of any of the 50 States. And we spend a lot of time on that.

Senator SESSIONS. That can't be.

Senator INHOFE. That is true, yes, it is. You are all saltwater down there.

Senator SESSIONS. A lot of it.

Senator INHOFE. But anyway, last June, this is an experience that you guys may not know about, I was down there at our place at Grand Lake, it is a huge lake. One my little granddaughters was down there, and it was Monday and I was going to have to catch a plane and come to Washington. And where I was swimming, I said, come on in, Molly, come on in. No, I don't want to, Papa. No, come on in. And finally she said, what is that green stuff down there? It looked like little amoebas floating around down in the water. I said, it is fine, there is no problem.

I got to Washington that night, I thought I was going to die for two nights. Because I got the blue green algae. I always thought people were faking it, but it is for real.

So that is the type of thing we are talking about now, and it is serious. In fact, people felt so sorry for the pain I was going through I even got a get well card from the Sierra Club.

[Laughter.]

Senator INHOFE. Because of all the factors that contribute to nutrient pollution, the levels may be impairing one body of water and may be healthy for another. And this is exactly what happened in my State of Oklahoma in four different lakes.

So I recently released a report exposing the high cost of the EPA's water regulations and the impacts on State and local government. The Clouded Waters report explores some of the major regional initiatives to control nutrient pollution in the Chesapeake Bay and Florida. These strict regulatory approaches are costly and have questionable environmental gains attached to them. I hope we can learn from these expensive, heavy-handed approaches and find ways to support States in developing scientifically sound management approaches to dealing with nutrient reductions that don't force an unfair choice between a healthy economy and a healthy ecosystem.

Thank you, Mr. Chairman.

[The prepared statement of Senator Inhofe follows:]

STATEMENT OF HON. JAMES M. INHOFE, U.S. SENATOR FROM THE STATE OF OKLAHOMA

I'd like to thank Chairman Udall for holding this hearing. I know the issue of uranium mill tailings remediation is of special concern to him and before that, to his father, Congressman Mo Udall, with whom I had the pleasure of serving in the House. I understand and share his concerns since we have one such site in Gore, Oklahoma. The Sequoyah Fuels Corporation operated as a uranium processing facility until 1992. In 2002, the Nuclear Regulatory Commission reclassified its wastes, bringing it under the authority of the Uranium Mill Tailings Radiation Control Act, authored by Congressman Udall.

The operations at many of these uranium mines and mills spanned decades and the associated remediation must also. This is a source of great frustration to many people impacted by these sites. I look forward to learning about the progress these agencies are making to clean up the Federal Government's uranium mining and processing legacy from the cold war.

In preparing for today's hearing, I am struck by the contrast between the levels of public health protection in the early decades of uranium mining with the requirements placed on modern day operations. NRC and EPA regulation of these facilities appears fairly comprehensive from groundwater protection requirements for In Situ Leach (ISL) mining to storage and disposal of tailings from conventional mines. For example, tailings can only be stored in specially constructed, "zero-discharge" facilities, with multiple liners and leak detection systems. Mill operators must also provide financial surety adequate to completely decommission the mill and reclaim the site. It is my hope that this thorough regulation of modern uranium mining reflects the lessons of our past, but does not inhibit the successful development of such facilities.

Our nation's economy depends on plentiful supplies of clean, affordable energy. Nuclear energy makes a crucial contribution to our energy supply, providing nearly 20 percent of our electricity—clean electricity that doesn't emit air pollutants. I hope to see this clean energy source grow in the near future. As our demand for uranium increases, it makes sense to me that we should harness domestic resources of uranium to a practical extent. This not only enhances our energy security, but also creates jobs: up to 300 jobs at each conventional mine and another 300 jobs at uranium processing mills.

We can't lose our focus on important efforts to clean up past activities, but we can't allow that legacy to obscure our development of clean energy. Modern uranium mining is vastly different from the government's unfettered activities in the 1950's. It is safer, cleaner, and supports the increased use of nuclear energy to meet our energy security needs. We need to maintain a balance between adequate protection of public health and safety, and the timely licensing of new uranium production facilities while we continue solving the uranium legacy left over from the cold war.

Senator CARDIN. Thank you, Senator Inhofe. You should listen to your granddaughter.

Senator INHOFE. Yes, I know it. I do from now on.

Senator CARDIN. Senator Whitehouse?

OPENING STATEMENT OF HON. SHELDON WHITEHOUSE, U.S. SENATOR FROM THE STATE OF RHODE ISLAND

Senator WHITEHOUSE. Thank you, Chairman Cardin. Thank you for hosting this hearing. And I want to thank the Ranking Member as well. This is a very important issue.

I would like to ask unanimous consent to add into the record of these proceedings an article entitled Dead Zones are Killing Ocean Ecosystems, by Jessica Wurtzbacher, who is an adjunct professor of biology at Roger Williams University in Rhode Island and lives in Jamestown. She reports that the number of dead zones around the world in the past 60 years has gone up nearly 10 times, from about 42 to over 400. And while the Baltic Sea is probably the biggest one, as has been mentioned already, the Gulf of Mexico is the biggest in the Continental United States. The Chesapeake Bay has very, very significant dead zones, occupying about 40 percent of the Bay in the summer.

And we in Rhode Island, in the Greenwich Bay area off of Narragansett Bay, saw a very significant fish kill a few years ago from a dead zone that erupted as warm waters and nutrients, contributed to an algae bloom that killed off the fish. But even if it is not killing off the fish, in a State like Rhode Island, where we are so proud of our coasts and where people come from all around the world to experience Rhode Island in the summer, a day at the beach with a red tide is not the kind of day that people are going to go home and say, that is a great place to go. It really has an economic effect, as well as the biological effects.

So I appreciate very much that you have held the hearing, and again, if I could have unanimous consent.

Senator CARDIN. Without objection, the entire article will be made part of our record.

[The referenced information was not submitted at time of print.]

Senator WHITEHOUSE. I appreciate it.

Senator CARDIN. Senator Boozman.

OPENING STATEMENT OF HON. JOHN BOOZMAN, U.S. SENATOR FROM THE STATE OF ARKANSAS

Senator BOOZMAN. Thank you, Mr. Chairman. I appreciate you and the Ranking Member allowing me to sit in on the Subcommittee. In the interest of time, I will submit something to the record.

Senator CARDIN. Thank you. Without objection, your statement will be made part of the record.

Now let me just introduce briefly our first panel of witnesses. First we have Bill Werkheiser. He is the Associate Director for Water for the U.S. Geological Survey. Mr. Werkheiser is responsible for USGS water related research and activities needed to understand our Nation's water Resources.

We have Nancy Stoner, who presently serves as the Acting Assistant Administrator for Water at the U.S. Environmental Protection Agency. Previously, Ms. Stoner served as the Deputy Assistant Administrator for Water at EPA.

Then we have Dave White. Mr. White was named Chief of the Natural Resources Conservation Service for the USDA in 2009. He provides overall leadership for activities of the Natural Resources Conservation Service to help people conserve, maintain and improve our natural resources and environment.

We will start with Mr. Werkheiser.

STATEMENT OF WILLIAM H. WERKHEISER, ASSOCIATE DIRECTOR FOR WATER, U.S. GEOLOGICAL SURVEY

Mr. WERKHEISER. Chairman Cardin, and members of the Subcommittee, thank you for the opportunity to appear before the Subcommittee with my colleagues from EPA and NRCS to testify on our research findings related to nutrients in the Nation's streams and aquifers.

Last year, USGS released the results of a comprehensive national assessment of nutrients in streams and groundwater that describe current nutrient conditions, how these conditions have changed over time, potential effects on humans and aquatic life, and important natural and human factors affecting nutrient concentrations. Our findings show that concentrations of nitrogen and phosphorus were 2 to 10 times greater than levels recommended to protect aquatic organisms in most agricultural and urban streams across the Nation.

Despite major Federal, State and local efforts to control point and non-point sources of nutrients, concentrations of nutrients have remained the same or increased in many streams and aquifers across the Nation since the early 1990's. There are some exceptions to these findings, but in general, these findings are consistent with relatively stable sources of nutrients from chemical fertilizer, manure and atmospheric deposition since the 1980's.

One of the most important hydrologic factors associated with high nitrogen concentration in streams is the presence or absence of subsurface tile drains. Tile drains are used in clay soils to prevent rapid dewatering of the root zone, which is necessary for healthy crops. Tile drains increase nutrient concentrations in streams by moving rainwater and nutrients from the soil rapidly to the streams. We found that areas with tile drains export about three times more nitrogen than other agricultural watersheds.

One of the most important findings in the assessment is that groundwater contributions of nitrogen to streams can be quite significant. For many of the streams we assessed, at least one-third of the total annual load of nitrate was contributed by groundwater flow into streams. This means that significant errors may be introduced into the nutrient load allocation process if nitrogen concentrations from groundwaters are not taken into account.

This also means that it is important to consider the relative importance of groundwater contributions before deciding which conservation practices are most appropriate. For example, conservation practices designed to reduce runoff to streams may have only a limited effect on nutrient loads in streams where groundwater contributions of nutrients are substantial.

Nitrate is a continuing human health concern in drinking water, particularly in shallow private wells and agricultural areas. Concentrations exceeded the current drinking water standard of 10 milligrams per liter in 7 percent of more than 2,000 private wells sampled by USGS. The quality and safety of water from private wells, which provide drinking water to about 15 percent of the U.S. population, are not regulated by the Safe Drinking Water Act. Rather, they are the responsibility of the individual homeowner.

Our findings show that the percentage of all sampled wells with nitrate concentrations greater than the drinking water standard increased from 16 percent to 21 percent since the early 1990's. In fact, we expect that nitrate concentrations are likely to increase in many private and public supply wells during the next decade as shallow groundwater with high nitrate concentrations move downward to the deeper parts of the aquifer used by many public water utilities.

There are two reasons for this. First, nitrate can persist in groundwater for years or even decades and may continue to be present at high concentrations because of past land management practices. Second, because of the slow movement of groundwater, there is a lag time between what happens on the land surface and chemical changes in water that reaches a deep well. What this mean is that water quality will likely get worse in many places before it gets better, regardless of what we do now. In fact, improvements in water quality that might resolve from reducing nutrient sources on the surface may not be apparent in some watersheds for years or even decades.

Thank you, Mr. Chairman, for the opportunity to share USGS research findings on this very important topic. I will be happy to answer any questions you or the other members may have.

[The prepared statement of Mr. Werkheiser follows:]

STATEMENT OF WILLIAM H. WERKHEISER
ASSOCIATE DIRECTOR FOR WATER, U.S. GEOLOGICAL SURVEY
DEPARTMENT OF THE INTERIOR
BEFORE THE SENATE COMMITTEE ON ENVIRONMENT & PUBLIC WORKS
SUBCOMMITTEE ON WATER AND WILDLIFE
OVERSIGHT HEARING NUTRIENT POLLUTION: AN OVERVIEW OF NUTRIENT REDUCTION APPROACHES
OCTOBER 4, 2011

Chairman Cardin and Members of the Subcommittee, I appreciate the opportunity to appear before the Subcommittee on Water and Wildlife of the Committee on Environment and Public Works with my colleagues from EPA and NRCS to testify on the findings of the U.S. Geological Survey (USGS) studies of nutrients in the Nation's streams and aquifers. I am William H. Werkheiser, Associate Director for Water.

The USGS serves the Nation by providing reliable scientific information to describe and understand the Earth; minimize loss of life and property from natural disasters; manage water, biological, energy and mineral resources; and enhance and protect our quality of life. Monitoring and assessment of water quality conditions in the Nation's streams and aquifers and research on the transport and fate of contaminants in the environment has been a fundamental part of the USGS mission for more than 100 years. Work on nutrients has been a major part of these efforts.

Nutrients are essential for healthy plant and animal populations and provide a range of benefits including increased food production for a growing global population. Too many nutrients, however, are not necessarily a good thing, and can have adverse effects on water quality, drinking water sources, recreation, and aquatic life. For example, excessive nitrate in drinking water can lead to "blue-baby syndrome", or methemoglobinemia, in which oxygen levels in the blood become too low, sometimes with fatal results. Elevated concentrations of nitrogen and phosphorus in streams, lakes, and estuaries can cause excessive growth of algae and other nuisance plants (a condition known as eutrophication). These plants can clog pipes and interfere with recreational activities such as fishing, swimming, and boating. Subsequent decay of algae can result in foul odors and a decrease in the amount of dissolved oxygen in water, also known as hypoxia. Hypoxic conditions, such as those found in the Gulf of Mexico, can harm fish and shellfish that are economically and ecologically important to the Nation. Data submitted by States in 2004, the most recent reporting date to the U.S. Environmental Protection Agency, indicate that 51 percent of the waters they surveyed are too contaminated for basic uses, such as fishing and swimming, because of their nutrient content. The U.S. Geological Survey recently completed a comprehensive national analysis of the distribution and trends of nutrient concentrations in streams and groundwater as part of the National Water Quality Assessment Program (Dubrovsky and others, 2010). The following statement provides an overview of some of the major findings from this analysis.

Occurrence and Distribution of Nutrients in Streams and Groundwater

Streams: Nutrients occur naturally in water, but elevated concentrations usually originate from man-made sources, such as artificial fertilizers, manure, and septic-system effluent. All five nutrients assessed – nitrate, ammonia, total nitrogen, orthophosphate, and total phosphorus – exceeded background concentrations at more than 90 percent of 190 sampled streams draining agricultural and urban watersheds.

Nutrient concentrations in streams are directly related to land use and associated fertilizer applications and human and animal wastes in upstream watersheds. Total nitrogen concentrations were higher in agricultural streams than in streams draining urban, mixed land use, or undeveloped areas, with a median concentration of about 4 mg/L – about 6 times greater than the average concentration of total nitrogen for 89 undeveloped watersheds (0.58 mg/L) sampled across the Nation. Nitrogen concentrations in agricultural streams generally were highest in the Northeast, Midwest, and the Northwest, which have some of the most intense applications of fertilizer and manure in the Nation. Concentrations in parts of the Midwest also are accentuated by artificial subsurface tile drains, which are used to promote rapid dewatering of poorly drained soils. Atmospheric deposition accounts for a significant portion of the nitrogen in streams in some relatively undeveloped watersheds, such as occur in the Northeast. Total nitrogen concentrations were lower in urban streams than in agricultural streams with a median concentration of less than 2 mg/L, but still about 3 times greater than background concentrations. Some of the highest concentrations in urban streams were downstream of wastewater-treatment facilities.

Total phosphorus concentrations were highest in streams in agricultural and urban areas, with a median concentration of about 0.25 mg/L – also about 6 times greater than the average concentration of total phosphorus for undeveloped watersheds that were sampled (0.034 mg/L). (Like nitrogen, high concentrations of phosphorus in agricultural settings are associated with high applications of fertilizers and manure. Urban sources may include treated wastewater effluent and septic-system drainage (in less urbanized settings), as well as runoff from residential lawns, golf courses, and construction sites.

The amounts of nitrogen and phosphorus leaving watersheds in streamflow – referred to as yields (expressed as mass per unit area) – rose with increasing nutrient inputs from nonpoint sources to a watershed, regardless of land use. In addition, 5 to 50 percent of the nitrogen input from nonpoint sources was exported out of most watersheds. Variability in watershed nutrient yields can be explained in part by differences in agricultural practices and in soils, geology, and hydrology. For example, agricultural lands with extensive subsurface tile drains are 3 times more likely to export more than 25 percent of applied nitrogen to streams than agricultural lands with fewer drains. However, less nitrogen is contributed to streams in the Southeast because of greater amounts of denitrification in the soil, as well as in shallow groundwater that ultimately discharges to streams. Less nitrogen also reaches western streams, but for different reasons – generally low amounts of precipitation and runoff, as well as the modification of flow systems by irrigation and impoundments. Phosphorus is less soluble and mobile than nitrogen and thus, phosphorus yields are lower than nitrogen yields for most streams.

<u>Groundwater</u>: Nitrate, the primary nutrient of concern in groundwater, exceeded background concentrations in 64 percent of shallow monitoring wells (depths of less than 100 feet below the land surface) in agricultural and urban areas. Concentrations of other nutrients in groundwater were not significantly greater than background concentrations. Nitrate concentrations in groundwater were highest (median of 3.1 mg/L) in shallow wells in agricultural areas that are associated with high fertilizer and manure applications. Nitrate concentrations were lowest in shallow wells in urban areas (median of 1.4 mg/L), and in deep wells in major aquifers.

The vulnerability of aquifers to nitrate does not depend solely on nutrient sources, but also on groundwater age and geochemical conditions that govern nitrate concentrations in groundwater. Nitrate concentrations were significantly higher in well-oxygenated (or "oxic") groundwater regardless of land use and nitrogen sources. For example, the median nitrate concentration for wells in agricultural areas was 5.5 mg/L in oxic water, but was almost undetectable in less oxygenated (or "reduced") water despite similar nitrogen inputs at the land surface. Nitrate concentrations are especially influenced by the combination of groundwater age and geochemistry; for example, concentrations greater than the U.S. Environmental Protection Agency (USEPA) Maximum Contaminant Level (MCL) of 10 mg/L as nitrogen were never found in groundwater with low dissolved-oxygen concentrations and recharged prior to 1950.

Groundwater contributions of nutrients to streams can be significant – particularly for nitrate. At least one-third of the total annual load of nitrate in two-thirds of 148 small streams studied across the Nation was derived from base flow, consisting mostly of groundwater. Groundwater also can contribute significant amounts of dissolved phosphorus to streams, particularly where natural sources of phosphorus are present in the aquifer and reduced chemical conditions favor phosphorus transport.

There are three important implications from this finding. First, for streams in which groundwater contributions of nutrients are substantial, crop management and irrigation practices, designed to reduce or slow the movement of overland flow to streams, may have only a limited effect on nutrient loads to streams. Second, improvements in water quality as a result of reductions in nutrient inputs on the land may not be apparent in streams for decades because of the slow rate of groundwater movement from the land surface through the subsurface to streams. Third, full accounting and assessment of groundwater contributions of nutrients to surface water is a critical step in developing management strategies to meet water quality goals for protection of drinking water supplies and aquatic life.

Natural processes – including physical, chemical, and biological – can affect exchanges between groundwater and streams. In stream settings containing organic-rich sediments and low dissolved-oxygen concentrations, bacteria convert dissolved nitrate in groundwater to innocuous nitrogen gas through the process of denitrification. These processes are most effective where the geometry of the local aquifer focuses most of the groundwater flow through organic-rich sediments. Nutrients can also be removed by plants in the riparian zone.

Some of the implications of these findings include:

- Nutrient concentrations in streams can be anticipated from information about land use and nutrient sources, along with natural features and management practices that affect the timing and amount of transport of nutrients over land and through the groundwater system.

- Hydrologic settings in which groundwater is least vulnerable to contamination are often those in which streams may be most vulnerable and vice versa. For example, artificial tile drains and ditches often greatly increase the transport of nitrogen from watersheds to streams, but may help protect groundwater from contamination.

Potential for Effects on Human Health

Streams: Nitrate concentrations in streams seldom exceeded the USEPA MCL of 10 mg/L as nitrogen. Nitrate exceeded the MCL in 2 percent of 27,555 samples and in 1 or more samples collected at 10 percent (50 of 499) of the streams assessed. Most streams with concentrations greater than the MCL drained agricultural watersheds and were particularly common in the upper Midwest, where the use of fertilizer and manure is relatively high and tile drains are common. Nearly 30 percent of agricultural streams had one or more samples with a nitrate concentration greater than the MCL, compared to about 5 percent of the streams draining urban land. About 12 percent of public supply intakes on streams are in watersheds draining agricultural areas. None of the samples from streams draining undeveloped watersheds had a concentration greater than the MCL. The implication of this finding is that utilities that withdraw water from streams in undeveloped or mixed land use watersheds, which account for more than 80 percent of the Nation's public-water supply intakes, are unlikely to encounter water with nitrate concentrations greater than the MCL.

Groundwater: Nitrate concentrations greater than the MCL are more prevalent and widespread in groundwater than in streams. Eighty-three percent of studies of shallow groundwater in agricultural areas found at least one sample with a nitrate concentration greater than the MCL (studies generally included 20 to 30 wells). Nationwide, concentrations exceeded the MCL in about 7 percent of 2,388 domestic wells. The quality and safety of water from domestic wells – which are a source of drinking water for about 15 percent of the U.S. population – are not regulated by the Federal Safe Drinking Water Act. Elevated concentrations were most common in domestic wells that are shallow (less than 100 feet deep) and located in agricultural areas because of relatively large nitrogen sources, including septic systems, fertilizer use, and livestock. Nitrate can persist in groundwater for years and even decades and may still be present because of previous land uses and management practices. These findings underscore the importance of public education and water-quality testing, particularly for wells associated with current or previously farmed land.

Concentrations exceeding the MCL were less common in public supply wells (about 3 percent of 384 wells). The lower percentage in public wells compared to domestic wells reflects a combination of factors including (1) greater depths and hence age of the groundwater; (2) longer travel times from the surface to the well, allowing denitrification and attenuation during transport; and (3) locations of most public supply wells near urbanized areas where sources of nitrate generally are less prevalent than in agricultural areas.

Even in relatively protected settings, advance planning is required for long-term protection of deep aquifers from nitrate contamination. Groundwater at all depths is part of an integrated flow system and can be vulnerable to future contamination as water moves downward from shallower, contaminated groundwater systems. The potential for future contamination of deep aquifers requires consideration because these aquifers commonly are used as sources of public supply and because restoration of the purity of this relatively inaccessible and slow-moving water is costly and difficult.

Effects on Aquatic Life

USGS findings show the status of streams with respect to region-specific USEPA recommended nutrient criteria, the response of aquatic biota to varying nutrient levels, and the status of streams with respect to USEPA ammonia toxicity criteria. Recommended nutrient criteria for nitrogen and phosphorus in streams and rivers have been established by USEPA for protecting beneficial ecological uses and preventing nuisance plant growth for different geographic regions of the country. USGS results show that measured concentrations of nitrogen and phosphorus were substantially greater than USEPA recommended nutrient criteria in most agricultural and urban streams in most regions across the Nation. Specifically, median concentrations of nitrogen and phosphorus measured at 135 agricultural streams typically were 2 to more than 10 times higher than recommended nutrient criteria. The frequent occurrence of stream nutrient concentrations that are much greater than USEPA recommended nutrient criteria, particularly in streams draining watersheds with significant agricultural and urban development, suggests that substantial reductions in sources of nutrients, as well as increased implementation of land and water management strategies designed to reduce nutrient transport, are needed to meet recommended criteria.

Chlorophyll a, a measure of algal biomass, along with concentrations of nitrogen and phosphorus, is used by USEPA, States, Tribes, and Territories to evaluate nutrient enrichment in streams. Findings suggest that relations between nutrients and chlorophyll a often are weak because other factors, including stream characteristics such as water temperature, flow, and canopy cover, can affect the growth of algal biomass regardless of nutrient concentrations. This results in a relatively wide range of algal response to nutrients in streams even within the same region. In addition, nutrient concentrations in some regions are so much greater than required for plant growth that additional increases in nutrients have little effect on plant biomass. The wide range in biological response to nutrient concentrations supports the need for a regional approach to nutrient criteria and for consideration of local factors related to stream habitat and flow characteristics in the development of these criteria.

Stream ecosystem health can be assessed by measuring the number and types of individuals comprising algal, macroinvertebrate, and fish communities to determine biological condition. Results show that the biological condition of all three communities, expressed as a percentage of the condition expected in minimally disturbed streams, declined with increasing concentrations of nitrogen and phosphorus. Changes were most pronounced for algal communities, in which the average biological condition in streams with elevated nutrients was only about 50 percent, compared to about 80 percent for streams with the lowest nutrient concentrations.

Concentrations of ammonia in streams seldom exceeded the USEPA criteria for protecting aquatic life from ammonia toxicity. Specifically, concentrations exceeded the acute criteria in only 33 samples from 7 streams, out of about 24,000 samples collected from 499 streams. Concentrations exceeded the chronic criteria in 139 samples from 22 sites. The acute and chronic criteria were most often exceeded in streams that drain watersheds with urban and mixed land uses in the semiarid west. Many of these streams also receive treated effluent from wastewater-treatment facilities. Few agricultural sites had concentrations greater than acute (1 site) or chronic (5 sites) criteria, despite relatively large fertilizer and manure sources. More stringent water-quality criteria for ammonia have been proposed by USEPA that could provide greater protection for aquatic life.

Changes in Nutrient Concentrations

Streams: Despite substantial Federal, State, and local efforts to reduce nonpoint-source nutrient loadings to streams and rivers across the Nation, including the Federal Water Quality Initiative from 1990 to 1995, trend analyses for 1993-2003 suggest limited national progress during this period in reducing the impacts of nonpoint sources of nutrients. Instead, nutrient concentrations have remained the same or increased in many streams and aquifers across the Nation and continue to pose risks to aquatic life and human health. These findings are consistent with relatively stable sources of nutrients since the 1980s, including use of fertilizers, applications of manure, and atmospheric deposition of nitrogen.

Sources of nutrients, however, are only one factor that can cause increases or decreases in concentrations. Nutrient concentrations also are influenced by natural variations in precipitation and streamflow, as well as by human activities that affect nutrient transport to streams, such as tile drains, conservation tillage, and other management practices. To focus on trends caused by humans, the USGS trend analysis used "flow-adjusted" nutrient concentrations. Flow adjustment, using long-term records of streamflow, removes variability and trends in concentrations likely caused by natural changes in streamflow. In streams with statistically significant flow-adjusted trends, upward trends were more common than downward trends. Specifically, flow-adjusted concentrations increased at 33 and 21 percent of sites for phosphorus and nitrogen, respectively, and decreased at 16 percent of sites for both nutrients. Increasing nutrient concentrations were most common in relatively pristine streams (those with nutrient concentrations less than USEPA's recommended regional nutrient criteria). Nearly 40 and 30 percent of these less impacted sites showed upward trends in phosphorus and nitrogen, respectively.

Groundwater: Estimates of groundwater recharge dates – the date when infiltrating water reaches the water table – show that concentrations of nitrate generally have increased since about 1975, consistent with trends in historical fertilizer use in the United States. These findings also are consistent with rates of groundwater flow, which can take years to decades to move water from the water table to a well. Nitrate concentrations were elevated in shallow wells as early as the 1950s and 1960s, whereas concentrations in deep aquifers were not elevated until the 1970s. Nitrate concentrations continued to increase in groundwater over the period 1988 to 2004. Overall, the proportion of 495 wells with concentrations greater than the USEPA MCL of 10 mg/L increased from 16 to 21 percent from the first to the second sampling period. Increases were most common in shallow groundwater beneath agricultural areas. Specifically, median nitrate concentrations increased in the agricultural shallow groundwater from 4.8 to 5.7 mg/L, whereas in deep groundwater in major aquifers, the median nitrate concentration increased from 1.2 to 1.5 mg/L. We expect that nitrate concentrations are likely to increase in aquifers used for drinking-water supplies during the next decade, or longer, as shallow groundwater with high concentrations moves downward into the groundwater system. Improvements in nutrient management practices on the land surface will likely take years to decades to result in lower nutrient concentrations in groundwater because of the slow rate of groundwater flow. Similar time delays also are expected for streams that receive considerable groundwater discharge.

Informing Nutrient Management Decisions

Water resource managers and policy makers have used hydrologic and chemical models to estimate current water-quality conditions for unsampled streams and to predict how conditions might change in response to alternative management actions. However, it's often difficult for decision makers to readily access model information and use models directly to evaluate a range of alternative scenarios. To address this limitation, the USGS has released an online, interactive decision support system that provides easy access to six newly-developed regional models using the SPARROW (SPAtially Referenced Regressions On Watershed attributes) modeling framework describing how rivers receive and transport nutrients from natural and human sources to sensitive waters, such as the Gulf of Mexico. These models were based on monitoring data collected by 73 different organizations from more than 2700 different stream locations that had sufficient data to calibrate the models. Results detailing nutrient conditions in each region are published in the Journal of American Water Resources Association, and can be accessed with the decision support system online.

By making this capability available over the internet in a user interface with familiar controls, modelers and water-resource managers alike can experiment with hypothetical scenarios and develop science-based estimates regarding the effects that specific contaminant sources or changes may have on water quality. These estimates can then be easily communicated to stakeholders and the general public via the same website. Equally important, the decision-support system provides estimates of model uncertainty to inform managers about the range of variability in model predictions of stream loads that can be attributed to uncertainties about how well the models describe actual water-quality conditions and the factors that influence these conditions. The SPARROW decision-support system can be accessed online at water.usgs.gov/nawqa/sparrow/dss.

Thank you, Mr. Chairman, for the opportunity to share USGS research findings on this very important topic. I will be happy to answer any questions you or the other Members may have.

References

Booth, N. L., Everman, E.J., Kuo I.L., Sprague, Lori, and Lorraine Murphy, Lorraine, 2011. A Web-Based Decision Support System for Assessing Regional Water-Quality Conditions and Management Actions. *Journal of the American Water Resources Association* (JAWRA) 1-15. DOI: 10.1111/j.1752-1688.2011.00573.x

Dubrovsky, N.M., Burow, K.R., Clark, G.M., Gronberg, J.M., Hamilton, P.A., Hitt, K.J., Mueller, D.K., Munn, M.D., Nolan, B.T., Puckett, L.J., Rupert, M.G., Short, T.M., Spahr, N.E., Sprague, L.A., and Wilber, W.G., 2010, The quality of our Nation's waters---Nutrients in the Nation's streams and groundwater, 1992-2004: U.S. Geological Survey Circular 1350, 174p.

U.S. Environmental Protection Agency, 2009, National Water Quality Inventory—Report to Congress, 2004 reporting cycle: U.S. Environmental Protection Agency, Office of Water, EPA 841-R-08-001, 37 p.c accessed June 17, 2010, at http://www.epa.gov/305b/2004report/2004_305Breport.pdf

Environment and Public Works Committee Hearing

October 4, 2011

USGS Responses to Follow-up Questions

Questions from Senator Cardin

Question 1: Please help us to better understand the scope and scale of the nutrient problem. How much work is needed for us to be able to get this problem under control? Is this a situation where, with a few minor adjustments, the nation's waters will become clean within a few years, or will this require more effort?

Response: The natural biogeochemical cycling of nitrogen and phosphorus has been extensively altered globally through production and application of fertilizers, cultivation of nitrogen-fixing crops, animal waste disposal, wastewater and industrial discharges, and combustion of fossil fuels (for nitrogen see Galloway and others, 1995, and Vitousek and others, 1997; for phosphorus, see Howarth and others, 2000, and Elser and Bennett, 2011). In the United States, the use of nitrogen and phosphorus fertilizers alone has increased by 10-fold and 4-fold, respectively, between about 1950 and the early 1980s. These human alterations have approximately doubled the rate of nitrogen inputs into the terrestrial nitrogen cycle and have greatly increased the transfer of nitrogen from rivers to estuaries and other sensitive receiving waters. Human activities also have profoundly influenced the cycling of phosphorus through the environment, increasing the environmental flow of phosphorus four-fold and doubling the rate of phosphorus delivery from land to the oceans.

The impact of the increased flow of nutrients into the environment on streams, groundwater, and coastal waters has been profound and widespread. Recent studies by the USGS and USEPA show that excessive nutrient enrichment is a widespread cause of ecological degradation in streams and that nitrate contamination of groundwater used for drinking water, particularly shallow domestic wells in agricultural areas, is a continuing human-health concern.

- USGS data show that most agricultural and urban streams across the Nation have measured concentrations of nitrogen and phosphorus 2 to 10 times greater than U.S. Environmental Protection Agency (USEPA) recommended nutrient criteria that generally represent nutrient levels that protect against the adverse effects of nutrient pollution (Criteria reported in USEPA, 2002; see list of references).

- Information provided by the States for the 2004 reporting cycle describing the condition of their assessed waters, as required under Section 305(b) of the Clean Water Act, indicates that nutrients are one of the leading causes of impairment in the nation's assessed waters. Impaired waters are unable to support one or more basic uses, such as fishing or swimming. In 2004, the states cited nutrients as a problem in 16% of impaired river miles, 19% of impaired lake acres, and 14% of impaired estuarine square miles. (USEPA, 2009)

- A national assessment of wadeable streams found that about 30 % of the nation's streams have high concentrations of nitrogen and phosphorus. In fact, of the stressors assessed in the survey, nitrogen and phosphorus are the most pervasive in the nation's streams, followed by excess sedimentation. Streams with high levels of these pollutants were found to be about two times more likely to have poor biological health USEPA, 2006).

- A survey of the nation's lakes, ponds, and reservoirs found that nearly 20% of lakes show high concentrations of nitrogen and phosphorus. Lakes with excess nutrients are 2 ½ times more likely to have poor biological health. (USEPA, 2010).

- The incidence of conditions in estuaries and coastal waters when dissolved-oxygen concentrations in water fall below levels necessary for healthy aquatic communities (a condition referred to as hypoxia) has increased 30-fold since 1960, affecting more than 300 water bodies. (National Center for Coastal Oceans Science, 2011). Hypoxic waters typically have dissolved oxygen-concentrations less than 2-3 mg/L that may result, in part from excess nutrients, primarily nitrogen and phosphorus, Excess nutrients can promote algal growth. As algae die and decompose, oxygen is consumed in the process, resulting in low levels of oxygen in the water. Impacted water bodies are located on all coasts of the Nation and the Great Lakes, including such critical resources such as the Gulf of Mexico, Chesapeake Bay, Puget Sound, and Lake Erie.

- In groundwater, nitrate concentrations exceeded the USEPA drinking-water standard Maximum Contaminant Level (MCL) of 10 milligrams per liter (as nitrogen) in 7 percent of about 2,400 private wells sampled by the USGS. Wells exceeding the MCL were widely distributed across the Nation: Nitrate concentrations exceeded the MCL in samples from one or more wells in 83 percent of studies of shallow groundwater wells in agricultural areas.

- Additional impacts of nutrient enrichment include toxic algal blooms, increased water treatment costs, increased concentrations of carcinogenic disinfection byproducts, and decreased recreational uses (fishing, swimming, and boating).

- USGS trend analyses suggest that despite major Federal, State and local nonpoint-source nutrient control efforts for streams and watersheds across the Nation, limited national progress has been made on reducing the impacts of nonpoint sources of nutrients during this period. Instead, concentrations have remained the same or increased in many streams and aquifers across the Nation, and continue to pose risks to aquatic life and human health. For example, nitrate transport to the Gulf of Mexico during the spring is one of the primary determinants of the size of the Gulf hypoxic zone. At times of high spring streamflow during the period studied, the concentration of nitrate decreased at the study site near where the Mississippi River enters the Gulf of Mexico, indicating that some progress has been made in reducing nitrate transport during high flow conditions. However, during times of low to moderate spring streamflow, concentrations increased. The net effect of these changes is that nitrate transport to the Gulf was about 10% higher in 2008 than 1980. This increase in nitrate transported to the Gulf can largely be attributed to the large upstream nitrate increases in the Mississippi River Basin above the Clinton, Iowa monitoring site and in the Missouri River Basin (Sprague and others, 2011). There are some exceptions to the findings in the Mississippi. For example, recent USGS findings show decreased nutrient concentrations in the Susquehanna and Potomac Rivers since 2000; but increasing concentrations in the Rappahanock and James Rivers (Hirsch and others, 2010).

These degraded conditions are the result of a massive increase in the amount of nutrients in the environment over more than six decades. Restoring beneficial uses will require effort and time on a similar scale. For example, the large amounts of nitrate already present in shallow groundwater in many agricultural areas of the country present one challenge (Puckett and others, 2011). Nitrate concentrations are likely to increase in aquifers used for drinking-water supplies during the next decade, or longer, as shallow groundwater with high concentrations moves downward into the groundwater system. Improvements in groundwater quality will likely lag behind changes in land-management practices by years or decades because of the slow rates of groundwater flow. Groundwater contributions of nutrients to streams can also be important, and thus, improvements in stream quality may also lag behind changes in land use practices by long time periods. The recent report on reactive nitrogen in the United States by the USEPA Science Advisory Board Integrated Nitrogen Committee recommended four goals of action to decrease reactive nitrogen entering the environment that, using existing and emerging technologies and practices, could potentially reduce loadings to the environment by about 25 percent within 10 to 20 years. The report also noted that "however, further reductions are undoubtedly needed for many N-sensitive ecosystems and to ensure that health-related standards are maintained" (USEPA, 2011a. p. 75-79).

More specific proposals for nutrient reduction have been developed for coastal receiving waters that have been severely degraded. For example, the Chesapeake Bay Program has developed nutrient reduction goals that would reduce zones of low oxygen and protect the ecological integrity of the Bay. Through a coordinated effort, each of the Chesapeake Bay States with tidal waters established water-quality standards for dissolved oxygen, chlorophyll *a,* and water clarity, all of which are designed to support ecological endpoints of living resources in a restored Bay. Water-quality models were then applied with equitable and consistent decision rules to determine the level of nutrient reduction needed in the watershed to attain the water-quality standards in all of the Bay mainstem segments, tidal tributaries, and embayments
(http://www.epa.gov/reg3wapd/pdf/pdf_chesbay/FinalBayTMDL/CBayFinalTMDLSection6_final.pdf). Based on that detailed methodology, the overall basin-wide reduction goals for the Chesapeake Bay were set at a 25 percent reduction in total nitrogen from 2009 estimated levels, and a 24 percent reduction in total phosphorus. For the Mississippi Atchafalaya River Basin, an analysis by the EPA Science Advisory Board has estimated that an even larger reduction—a 45 percent reduction in both nitrogen and phosphorus—is needed to reduce the size of the hypoxic zone to the established goal of less than 5,000 square kilometers (USEPA, 2008); the size of the zone in late summer of 2011 was 17,520 square kilometers.

Nutrient management strategies need to be dynamic and capable of responding to unanticipated changes that occur to the natural and anthropogenic factors affecting water-quality conditions. The history of the water-quality conditions in Lake Erie serves as an example of the types of changes that can occur (USEPA, 2011b). In response to massive blooms of blue-green algae in Lake Erie during the 1960s, the U.S. and Canada forged the 1972 Great Lakes Water Quality Agreement which led to an approximate 60% reduction in phosphorus loading to Lake Erie. Lake Erie responded with reduced phosphorus concentrations, and no massive algal blooms were reported during the 1980s. Due to the interactions of nutrient enrichment and invasive species—Zebra mussels, which arrived in the mid-to late-1980s—large algal blooms reappeared by the mid-1990s and persisted through 2006. Moreover, unlike earlier blooms, these have been dominated by the blue-green alga *Microcystis aeruginosa,* which produces the toxin microcystin. Although it is believed that some water treatment procedures can be effective in removing the toxin, this is of concern to the municipalities along the lakeshore that obtain drinking water from Lake Erie. Water-quality monitoring and assessment can help to identify important shifts in water quality conditions and provide the understanding needed to guide changes to nutrient management strategies.

Question 2: During the hearing we heard you speak about some of the source sectors of nutrient pollution. Can you give a bit more detail of the various sectors involved, including: agriculture, wastewater treatment, air deposition, street runoff, and residential lawns? Please provide us with the extent to which each source sector contributes to the total problem of nutrient pollution.

Response: Different sources of nutrients predominate in different regions of the country and are described in Dubrovsky and others (2010) (See http://water.usgs.gov/nawqa/nutrients/pubs/circ1350/ and Preston and others (2011) (See http://water.usgs.gov/nawqa/sparrow/mrb/).

- Agriculture is the largest source of nutrients throughout most of the upper Midwest, as well as in other parts of the Nation where agriculture is the predominant land use. Commercial fertilizer and other sources of nutrients associated with cultivation (e.g., manure applied as fertilizer, Nitrogen fixation[1] by legumes, mineralization) are the major sources of nitrogen throughout the upper Midwest. Manure is the dominant nitrogen source throughout much of the upper Missouri, lower Mississippi, and western Gulf of Mexico drainages. Manure is also identified as the major source of phosphorus on a much more widespread basis than nitrogen in all of the regions except the Pacific Northwest.

- Urban sources—Treated effluent from point sources and urban runoff from developed land tend to be locally dominant in major urban areas throughout the Nation. Treated wastewater effluent can be the dominant source of nitrogen in some urban streams, particularly during the dry season in areas of the semiarid West.

[1] Soybeans and alfalfa are legumes that use atmospheric nitrogen gas as their primary source of nitrogen. These plants are able to "fix" nitrogen gas from the atmosphere to create a form of nitrogen needed for plant growth and reproduction.

- Atmospheric deposition is the largest nonpoint source of nitrogen in undeveloped watersheds in the eastern part of the country where the deposition rates are highest, such as in the Connecticut River Basin, in areas near the Great Lakes, and the arid and mountainous West where human development is very sparse.

The loading at any particular point in a stream is also a function of where the sources in the watershed are located. An online, interactive decision support system that was recently released by the USGS provides easy access to the six regional models described in Preston and others (2011). http://water.usgs.gov/nawqa/sparrow/mrb/ and the ability to determine the largest sources of nutrients to specific stream reaches. These relatively detailed characterizations of nutrient sources have been accomplished despite major deficiencies in available data. Improved accounting and tracking of nutrient sources would facilitate development of more efficient and cost effective nutrient management plans. Improvements in the data for the following sources would be helpful.

- *Point Sources*: Data from USEPA's Permit Compliance System (PCS) national database was used to estimate annual loads of nitrogen and phosphorus discharged to streams from individual municipal and industrial facilities. Concentration and effluent flow data were examined for more than 118,000 facilities in 45 states and the District of Columbia. Inconsistent and incomplete discharge locations, effluent flows, and effluent nutrient concentrations limited the use of these data for calculating nutrient loads. Reporting from facilities discharging more than 1 million gallons per day was more complete than for smaller facilities. Annual loads were calculated using "typical pollutant concentrations" to supplement missing concentrations based on the type and size of facilities. Annual nutrient loads for about 22 percent of the facilities were calculated in this manner for at least one of the three years studied (Maupin and Ivahnenko, 2011), More work is needed in this area.
- *Fertilizer use*: Annual fertilizer sales data are compiled by the Association of American Plant and Food Control Officials (AAPFCO) (Gaither and Terry, 2004) from annual State reports. Because of the absence of national reporting requirements, there are inconsistencies in the level of detail provided. This is especially true for non-agricultural sales estimates, as the reporting of the code distinguishing farm and non-farm use is optional (Ruddy, 2006). Because the AAPFCO data report the point of fertilizer sales and not the point of use, it is critical that the U.S. Department of Agriculture (USDA) continues to collect fertilizer expenditures data—which reflects the point of use—as part of the Census of Agriculture (U.S. Department of Agriculture, 2006).

- *Concentrated Animal Feeding Operations (CAFOs)*: Information on the number of animals (used to estimate loadings of animal manure) is available by county from the Census of Agriculture. But, this scale is generally too coarse to be able to associate estimates of manure loadings to specific watersheds and downstream monitoring. If the loadings are attributed to the wrong streams or spread out over a large area such as a county, then their influence may not be captured accurately or at all using water-quality models.

Question 3: Which regions, according to the United States Geological Survey's data and information, have the highest nutrient pollution levels? Why?

Response: Concentrations of nutrients occur at elevated levels in developed landscapes in all regions of the country. More specific characterizations of which regions have the highest nutrient pollution levels can be made by breaking the question down into three specific perspectives: with respect to drinking water standards; with respect to ambient water quality criteria for streams; and for ecological condition of receiving waters (lakes and estuaries).

Which regions have the highest nutrient pollution levels with respect to drinking water? Most streams with concentrations greater than the drinking water standard for nitrate, or Maximum Contaminant Level (MCL) are located in the upper Midwest (Dubrovsky and others, 2010). These streams had high concentrations of nitrate because they drain agricultural watersheds where fertilizer and (or) manure application rates are among the highest in the Nation. The elevated concentrations also reflect landscape characteristics and land-management practices that promote rapid transport of runoff from fields to streams, including relatively impermeable soils and artificial drainage, such as subsurface tile drains. Nitrate concentrations greater than the MCL are uncommon in streams draining watersheds dominated by other land uses, and nonexistent in samples from streams draining undeveloped watersheds. (See question 6 for additional detail.)

In contrast to streams, groundwater with concentrations exceeding the MCL were widely distributed across the Nation: 83 percent of studies of shallow groundwater in agricultural areas had one or more samples (of 20 to 30 wells sampled) with a nitrate concentration greater than the MCL. Nitrate concentrations greater than the MCL are most common in areas with favorable geochemical conditions (that is, groundwater with dissolved oxygen; see McMahon and others, 2009), with young groundwater (recharged after 1952), and with larger inputs of nitrogen to the land surface.

Which regions have the highest nutrient pollution levels with respect to ambient water quality criteria for streams? USGS data show that exceedance of recommended nutrient criteria that generally represent nutrient levels that protect against the adverse effects of nutrient pollution (USEPA, 2002) is widespread in developed landscapes. In fact, as noted in question 1 above, agricultural and urban streams across the Nation have measured concentrations of nitrogen and phosphorus 2 to 10 times greater than these recommended criteria (see chapter 7, Dubrovsky and others, 2010). These data indicate that both agricultural and urban sources are routinely capable of producing elevated instream concentrations.

Which regions have the highest nutrient pollution levels with respect to the ecological condition of receiving waters? Excessive loading of nutrients has degraded the ecological condition of lakes and estuaries throughout the country. Degradation of these waters has been documented in reports by States to the USEPA (USEPA, 2009) and the National Oceanic and Atmospheric Administration (NOAA). For example, NOAA reported that "The majority of U.S. estuaries assessed displayed at least one symptom of eutrophication, suggesting a large-scale, national problem" (Bricker and others, 2007). They further reported that estuaries with highly eutrophic conditions were most common in the Mid-Atlantic region, and occurred in all regions of the nation except the North Atlantic.

Although the scope of the USGS National Water Quality Assessment Program does not include coastal waters, USGS monitoring of the mass of nutrients transported by major rivers to coastal waters provides the critical data that link the condition of these resources to upstream sources of nutrients. Note that unlike the metrics for assessment of drinking water quality and ecological impact which are based on concentration (mass per unit volume, such as milligrams per liter), controlling excess nutrient levels in coastal waters is also a function of the mass of nitrogen and phosphorus delivered per unit time, expressed as "load" (with units such as tons per year). Monitoring of loads at upstream sites can also be converted into yields (mass per unit area, calculated as mass transported by a river divided by the drainage area of the river basin) to identify areas that contribute the largest amount of nutrient per unit area of watershed. For example, application of the SPARROW model to watersheds draining to the Great Lakes determined that the highest loads were from tributaries with the largest watersheds, whereas highest yields were from areas with intense agriculture and large point sources of nutrients (Robertson and Saad, 2011). These calculations facilitate the ranking of tributaries for prioritization of remediation efforts based on their relative loads and yields to each lake.

The National Lakes Survey showed that lakes within the northern, temperate, and coastal plains of the United States had the highest concentrations of nutrients as compared to other regions of the United States. The temperate plains showed 60% and 70% of lakes exceeded regionally specific reference based thresholds for phosphorus and nitrogen, respectively. The coastal plains showed 50% and 45% of lakes exceeded regionally specific reference based thresholds for phosphorus and nitrogen, respectively. Finally, the northern plains showed 70% and 90% of lakes exceeded regionally specific reference based thresholds for phosphorus and nitrogen, respectively. This high level of nutrients in the northern plains is also coupled with the highest taxa loss for any region of the nation, with regard to lakes, with phytoplankton communities showing greater than 40% taxa loss in greater than 90% of the lakes in this region (USEPA, 2010).

Question 4: Nutrient pollution can cause algal bloom growth, leading to "dead zones," or areas where no plant or animal life can survive. How do algal blooms create "dead zone"? What do these dead zones mean for water bodies like the Chesapeake Bay? What are some of the ecological harms associated with these dead zones? What are some of the economic harms associated with dead zones?

Response: The term "dead zone" is often used to describe areas that are hypoxic, or contain low concentrations of dissolved oxygen (generally 2 to 3 milligrams per liter). Hypoxia can be caused by saline and temperature gradients and excessive nutrients. Hypoxia in the northern Gulf of Mexico is caused by excess nutrients delivered from the Mississippi River in combination with seasonal stratification of Gulf waters. Excess nutrients promote algal growth. When the algae die, they sink to the bottom and decompose, consuming available oxygen. Stratification of fresh and saline waters prevents mixing of oxygen-rich surface water with oxygen-depleted bottom water. Immobile species such as oysters and mussels are particularly vulnerable to hypoxia and become physiologically stressed and die if exposure is prolonged or severe. Fish and other mobile species can avoid hypoxic areas, but these areas still impose ecological and economic costs, such as reduced growth in commercially harvested species and loss of biodiversity, habitat, and biomass (Committee on Environment and Natural Resources, 2010). Fish kills can result from hypoxia, especially when the concentration of dissolved oxygen drops rapidly.

The effect of hypoxia is to decrease productivity and resilience of exploited populations, making them more vulnerable to collapse in the face of heavy fishing pressure.
The ecological impacts of hypoxia may be described in terms of the ecosystem services normally provided by a healthy ecosystem, but lost as a result of hypoxia. A full assessment of ecosystem services lost helps bridge the gap between ecological functions lost and their impact on people. In some cases, though not without challenges, ecosystem services can be assigned a reasonable dollar value. In these cases, analysis of services helps convey the economic costs associated with ecological impacts.

Fisheries yield is one ecosystem service that can be impacted both directly and indirectly by hypoxia. Mortality of fisheries species is a direct mechanism by which services are lost. Loss of forage for bottom-feeding fish and shellfish due to hypoxia is probably more important in most cases. In the Chesapeake Bay, seasonal hypoxia lasts about three months and reduces the Bay's total benthic secondary production[2] by about 5% (Diaz and Schaffner, 1990), or roughly 75,000 metric tons of biomass (Diaz and Rosenberg, 2008). This is enough to feed about half the annual blue crab catch for a year. In the northern Gulf of Mexico, severe seasonal hypoxia can last up to six months and reduces benthic biomass by about 212,000 metric tons when the hypoxic zone is 20,000 km^2 (Rabalais and Turner, 2001). This lost biomass could feed about 75% of the brown shrimp catch for a season (Diaz and Rosenberg, 2008

One of the less obvious ecosystem services lost during hypoxia is sediment mixing by benthic organisms, or 'bioturbation.' Reworking of sediments via bioturbation promotes oxygenation of sediments, improving habitat for benthic animals and promoting biogeochemical feedback processes that reduce nutrient recycling and limit eutrophication. There are a growing number of literature citations on the ecological consequences of hypoxia, but economic evaluations are lacking. Economic effects attributable to hypoxia are subtle and difficult to quantify even when mass mortality events occur. Much of the problem is related
to multiple stressors (habitat degradation, overfishing, Harmful Algal Blooms, and pollution) acting on targeted commercial populations as well as factors that impact fishery' economics (aquaculture, imports, economic costs of fishing, and fisheries regulations). Economic impacts that stem from the effects of hypoxia on fishery stocks are mostly tied to ecological
impacts through reduced growth and reproduction. Other economic costs imposed on fishers are related to increased time on fishing grounds and costs of to reach more distant fishing grounds beyond areas impacted by hypoxia. How these costs translate to impact on profits is complex, however, because in addition to the ramifications of reduced quantity, the unit value of landings on the market affects its total value and must be considered when evaluating the economic impacts.

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[2]Secondary production refers to the mass of organisms near the base of the food web that are produced in a season or year in a given area. Benthic refers to organisms that live on or near the bottom of rivers, lakes, and oceans. Benthic secondary production is usually expressed as grams of carbon per square meter or per square kilometer (km^2).

Although quantifying costs of hypoxia-related mortality events is difficult, there are some published examples. Hypoxia in the early 1970s in Mobile Bay, Alabama was estimated to have killed over $500,000 worth of oysters (May, 1973). An even greater economic cost was associated with the declining stock size associated with mortality and poor recruitment of oysters in years with severe hypoxia. A modeling study in the Patuxent River in Maryland estimated that the net value of striped bass fishing alone would decrease over the long-term by over $145 million if the entire Chesapeake Bay were impacted by hypoxia, which would preclude fishing in other sites (Lipton and Hicks, 2003). Impacts of hypoxia on the overall health of the striped bass population and impacts to other Chesapeake fisheries were not included in this estimate but would substantially increase the overall economic consequences to fishers in the region.

Question 5: Based on your data, nutrient levels in groundwater are contributing substantially to the problems of nutrient pollution that we see today.

a. Are there different approaches to reducing nutrient levels in groundwater vs. in surface water?

Response:
Approaches used to reduce nutrient levels from nonpoint sources in groundwater and surface water usually involve manipulating the amount, timing, form, and method of application of fertilizer and other sources of the nutrients. However, Ribaudo and others (2011) concluded that: "Reducing the application of nitrogen fertilizers appears to be the most effective Best Management Practice (BMPs) for reducing the emission of nitrogen into the environment" because most of the BMPs used to minimize nutrient transport to streams via surface runoff (dissolved transport) and erosion (particulate transport) increase the amount of time that water from precipitation or irrigation remains on the agricultural fields. The longer the water remains on the field the greater the potential for infiltration and the potential for transport of dissolved nitrogen to groundwater. (Note that phosphorus is usually not transported to groundwater because of its low solubility and tendency to bind to soils and aquifer materials.) Methods that minimize the exposure of nitrogen to runoff by incorporating the fertilizer into the soil also increase the transport of dissolved nitrogen to groundwater.

b. What do these differences mean for our attempts to reduce nutrient pollution in our waters?

These differences mean that the benefits of using BMPs to protect streams by retarding runoff must be carefully weighed against the potential for these practices to increase groundwater contamination. A recent summary on the topic by the USDA Economic Research Service concludes that: "in areas where leaching to drinking water sources is a concern, improvements in nitrogen use efficiency could focus on application rate reductions or improvements in timing" (Ribaudo and others, 2011).

In areas where management measures promote transport of nitrogen from runoff to groundwater, we trade a near-term improvement in stream quality for the potential long-term degradation of groundwater, along with the prospect that the high-nitrogen groundwater may eventually discharge to a stream in the future. In some riparian zones next to streams, where groundwater moves through organic rich soils, nitrate can be transformed by microorganisms to harmless nitrogen gas, a scenario in which the threat to both streams and groundwater resources is ameliorated.

Question 6: What impact does nutrient pollution have on human health?

Response: Elevated concentrations of nutrients, particularly nitrate, in drinking water may have both direct and indirect effects on human health. The most direct effect of ingestion of high levels of nitrate is methemoglobinemia, a disorder in which the oxygen-carrying capacity of the blood is compromised; the USEPA Maximum Contaminant Level (MCL) of 10 mg/L for nitrate in drinking water was adopted to protect people, mainly infants, against this problem. High nitrate concentrations in drinking water also have been implicated in other human health problems, including specific cancers and reproductive problems (Ward and others, 2005), but more research is needed to corroborate these associations. The indirect effects of nutrient enrichment of surface waters on human health are many and complex, including algal blooms that release toxins and the enhancement of populations of disease-transmitting insects, such as mosquitoes (Townsend and others, 2003).

Nitrate concentrations in streams across the nation seldom exceeded the USEPA MCL of 10 mg/L as nitrogen—nitrate exceeded the MCL in two percent of 27,555 samples, and in 1 or more samples from 50 of 499 streams (Dubrovsky and others, 2010). Nitrate concentrations greater than the MCL are more prevalent and widespread in groundwater than in streams. Concentrations exceeded the MCL in seven percent of about 2,400 private wells sampled by the USGS. Contamination by nitrate was particularly severe in shallow private wells in agricultural areas, with more than 20 percent of these wells exceeding the MCL. The quality and safety of water from private wells—which are a source of drinking water for about 15 percent of the U.S. population—are not regulated by the Federal Safe Drinking Water Act.

Concentrations exceeding the MCL were less common in public-supply wells (about three percent of 384 wells) than in private wells. The lower percentage in public wells reflects a combination of factors, including: (1) greater depths and hence age of the groundwater; (2) longer travel times from the surface to the well, allowing denitrification and (or) attenuation during transport; and, (3) locations of most public wells near urbanized areas where sources of nitrate generally are less prevalent than in agricultural areas.

Nitrate concentrations are likely to increase, in deep aquifers typically used for drinking-water supplies during the next decade, despite nutrient reduction strategies, as shallow groundwater with high nitrate concentrations moves downward to deeper aquifers. USGS findings show that the percentage of sampled wells with nitrate concentrations greater than the USEPA drinking water standard increased from 16 to 21 percent since the early 1990's. Similarly, the probability of nitrate concentrations exceeding the MCL has increased from <1% in the 1940's to >50% by 2000 for young groundwater in agricultural settings (Puckett and others, 2011).

Nitrate can persist in groundwater for years or decades and may continue to occur at concentrations of concern to human health because of previous land management practices. Because of the slow movement of groundwater, there is a lag time between what happens on the land surface and chemical changes in water that reaches a deep well. This means that improvements in water quality that might result from reducing nutrient sources on the surface may not be apparent in some watersheds for years or even decades.

Question 7: Do you think a nutrient-trading program would be an effective way to manage and reduce nutrient pollution? Why or why not?

Response: Nutrient trading is now widely expected to increase the cost-effectiveness and efficiency of aquatic nutrient control. Nutrient trading programs are operating in watersheds in 15 States and three other countries, and are under development in many additional jurisdictions (Selman and others, 2009). It is estimated, for example, that nitrogen trading among publicly owned treatment works in Connecticut will ultimately save over $200 million dollars in achieving the nitrogen reductions required under a Long Island Sound TMDL (USEPA, 2003). Preliminary findings from USGS research and use of USGS models show that total national savings of several billion dollars per year would result from expanding trading markets to regional scales, including full participation of both point and nonpoint sources, and optimizing both the location of nitrogen controls and the control technologies employed (Smith and others, 2008).

Questions from Senator Inhofe

Question 8: At the hearing you discussed that contributions of groundwater must be taken into account for TMDLs for surface waters. A Franklin & Marshall University study on the Chesapeake Bay watershed and a study by Agricultural Research Service hydrologist Glenn Wilson on the Mississippi River watershed both indicate that a large amount of the sediment that reaches the Chesapeake Bay or the Northern Gulf of Mexico is from stream bank erosion, and is not from the surrounding land. How can these contributions be better taken into account when developing TMDLs?

Response:

Accounting for groundwater contributions when developing nutrient TMDLs for streams: Standard methods exist to estimate the percentage of streamflow that is from groundwater, and to estimate the percentage of nutrient loads that come from groundwater discharge. Bachman and others (1998) and Spahr and others (2010), provide examples of how this has been done at the regional (Chesapeake Bay area) and national levels, respectively. Both studies used streamflow records to estimate the proportion of annual flow that is from groundwater discharge, and then used water-quality measurements and streamflow records together to estimate the proportion of the annual load of selected nutrients that is carried to the stream by groundwater discharge.

The graphical methods used by Spahr and others (2010) and Bachman and others (1998) could be used to better understand the role of groundwater discharge to streams in other areas. It is commonly recognized that the graphical methods generally underestimate the amount of groundwater discharge during storm events (Sklash and Farvolden, 1979), but the method continues to be used because the method: 1) only requires a streamflow record (which is available for most gaged streams across the United States), and 2) provides an initial estimate that can be used to understand the general patterns of groundwater discharge.

Progress towards reaching a TMDL may be difficult in watersheds where a large percentage of the nutrient load is from groundwater discharge. The difficulty arises in understanding the lag time between when water and nutrients enter an aquifer, and when they subsequently discharge to streams. Models can be used to help predict groundwater residence times (Sanford and Pope, 2007). Such models can estimate mean lag times for watersheds, and predict future changes in stream loads given future changes in nitrogen loadings to the land surface. Measurements of chemicals known as age-dating tracers in shallow groundwater, and in some cases streams, can help estimate groundwater lag times. At the watershed scale, even the initial water-quality improvement in surface water bodies may not be seen for years, and even if management practices were implemented basin-wide, the full response may not be seen for decades. However, practices are rarely implemented across an entire basin simultaneously, thus making it even more difficult to observe responses in surface water bodies. In addition, the larger the watershed, the longer the length of time before changes in water quality due to groundwater discharge will occur.

Thus, we can determine the magnitude of the nutrient load contributed by groundwater to a stream and the practices that are available to manage those loads. However, monitoring the response to those changes may require novel approaches such as monitoring of shallow groundwater near streams, because it may take years before changes in water quality can be observed in the stream itself.

Accounting for streambank erosion in the development of sediment TMDLs: The relative importance of streambank erosion to instream sediment loads is increasingly recognized within and outside of the United States (Trimble, 1997; Walling and others, 1999; Simon and Rinaldi, 2006; Gellis and others, 2009), indicating that accurate accounting of streambank erosion is necessary to adequately manage stream and river sediment loads. While there are no widely accepted models that predict rates of bank erosion across a wide range of environments (De Rose and Basher, 2011), advances in geographic information systems, surveying techniques, modeling, and computing power continue to improve the tools that enable scientists and water-quality managers to characterize streambank erosion processes.

USGS has developed statistical models (SPARROW) that use existing streamflow, sediment, and spatial data to characterize factors influencing suspended-sediment loads at regional and national scales (Schwarz, 2008; Brakebill and others, 2010). These models account for erosion and/or deposition of sediment from different land uses and in stream channels, and can be accessed and manipulated (in the case of Schwarz, 2008) through a new decision support system (http://cida.usgs.gov/sparrow/) that provides the user with the ability to characterize the relative importance of various sediment sources at user-defined locations on a mean-annual basis. These models conclude that streambanks represent a significant source of sediment loads. While these sediment models have the potential to quickly inform managers of the relative importance of various sediment sources (as well as the certainty with which those sources can be ascribed), the accuracy and timeliness of these models for the future is likely to be limited by the decline in sediment monitoring that has occurred over the last two decades (Gray, 2002).

Existing spatial datasets have also been used to characterize the relative importance of streambank erosion to downstream water bodies. These datasets include historical and current aerial photography (Lawler, 1993; Trimble, 2008) and LIght Detection And Ranging (LIDAR) techniques which provide accurate, spatially-detailed elevation datasets (Thoma and others, 2005; Newell and Clark, 2008). The USGS Earth Resources Observation and Science (EROS) center works to archive and serve these and other sources of data for scientists and managers (http://eros.usgs.gov).

While the analysis of existing sediment and spatial data can provide information on long-term, average sediment contributions from streambanks, understanding the mechanisms and causes of streambank erosion requires more intensive data collection and/or modeling efforts. Wilson and his colleagues, whose work is referenced in the question, have published on various processes that affect streambank failure http://www.ars.usda.gov/is/AR/2011/feb11/streambanks0211.htm, and have incorporated their findings into the Bank Stability and Toe Erosion model. While the science is far from settled, it is clear that streambank erosion is an important process; and that the type of process research that Wilson and others are doing is an important/critical complement to instream and field monitoring efforts that are necessary to help refine and improve watershed models such as SPARROW. New surveying techniques, such as aerial (Kinzel and others, 2006; McKean and Isaak, 2009) and terrestrial LIDAR (Collins and Kayen, 2006) can provide more temporally-dense, site-specific estimates of streambank erosion. Compilation of sediment budgets through surveys and through the collection of physical and geochemical sediment tracers have allowed researchers to quantify the relative importance of various sediment sources (Walling, 2005; Gellis and Walling, 2011). In addition, the USDA has developed models that simulate bank erosion processes using available and newly collected data (Langendoen and others, 2001; Simon and others, 2011).

Question 9: Some areas of the country have extensively modified streams and rivers, which were channelized into concrete lined flood control channels

Should nutrients in concrete lined flood control channels be regulated the same as natural streams?

Response:
States have some degree of flexibility under the Clean Water Act regarding how they apply Clean Water Act standards to a specific waterbody. Concrete-lined flood control channels may or may not meet the statutory and regulatory definition of "waters of the United States" and therefore may or may not be subject to the provisions of the Clean Water Act.

If a specific waterbody such as a heavily modified stream is jurisdictional under the Clean Water Act, States have some flexibility under the Clean Water Act in how they apply water quality standards to that waterbody. For example, states may be able to tailor the specific designated uses of a particular waterbody to its characteristics. Where a State determines that achieving a designated use that provides for the protection and propagation of fish, shellfish, and wildlife or recreation in and on the water (e.g., a Clean Water Act section 101(a)(2) aquatic life or recreation use) is not attainable, States may change the designated use of a water by conducting an assessment of what uses are attainable. If a State analysis supports a change in the designated use, States may change the designated use in their Water Quality Standards regulations. A change in designated use can often result in a change to the water quality criteria that must be met. See (http://water.epa.gov/scitech/swguidance/standards/uses/uaa/index.cfm)

How should nutrient criteria for these altered habitats (warmer water temperature, no reproducing populations of fish and poor general habitat) be different than the criteria for more natural streams?

Response: Under the CWA, States must adopt water quality criteria to protect the designated uses that have been previously set by the State. If the State determines that the designated use for an altered habitat is not achievable, then the State can conduct a use attainment analysis. EPA's Web site contains information on water quality standards and use attainment analysis that may apply to the situation in the preceding question. Many of our waters do not meet the aquatic life or recreation water quality goals envisioned by Section 101(a)(2) of the Clean Water Act. In some cases, it will not be possible to reach this water quality goal and States have the ability to demonstrate through analysis that the Clean Water Act section 101(a)(2) aquatic life or recreation use goal is not attainable for a particular water and to establish a different designated use in their WQS regulations based on this analysis. See (http://water.epa.gov/scitech/swguidance/standards/uses/uaa/index.cfm)
EPA's regulations require that States must also ensure attainment of standards in downstream waters. This is important as modified streams may carry nutrients to downstream waters. States can establish numeric water-quality criteria based on EPA's recommended Section 304(a) criteria guidance, modifications of the guidance recommendations reflecting site-specific conditions, or criteria based on other scientifically defensible methods.

Question 10: Does USGS have suggestions for measuring the success of nutrient management programs, given they may not achieve their goals for years or decades?

Response: USGS recommends four actions that will enable long-term evaluation of the success of nutrient management programs locally and nationally:

1) Restore and enhance multi-scale, long-term monitoring of nutrients in the Nation's surface water and groundwater resources.

2) Improve existing water-quality models for extrapolation of nutrient occurrence in space and time.

3) Establish a network of targeted watershed studies that track nutrients from source areas to receiving waters and groundwater discharge locations across a representative range of nutrient management programs.

4) Improve the detail and reliability of information on sources of nutrients, and establish requirements that all nutrient management programs document the type, location, and extent of practices implemented in each watershed or aquifer.

The first three actions are largely included as part of recommended plans for the next 10 years of the National Water Quality Assessment Program. Accomplishing these tasks would require substantial rebuilding and enhancements of current monitoring and assessment activities to address these critical public issues. The National Research Council (2011) has reviewed the plans and supports the recommendations. However, at present, agency resources are insufficient to fully address these needs. The fourth action is a critical information requirement; but should be addressed by those agencies responsible for nutrient management programs.

It is worth recognizing that existing USGS efforts can complement the significant work underway by the EPA and States under the Clean Water Act. For example, the EPA/State National Aquatic Resource Surveys are effectively using limited resources to survey nutrients and other core parameters and report on changes at the national and regional scale of the condition of the nation's surface waters, including rivers, streams, lakes, reservoirs, and coastal waters. States allocate some of the Nonpoint Source Program grants under Section 319 of the Clean Water Act to monitoring the localized effectiveness of best management practices, including those aimed at reducing nonpoint source nutrient loads.

References:

Alexander, R.B., Smith, R.A., Schwarz, G.E., Boyer, E.W., Nolan, J.V., and Brakebill, J.W., 2008, Differences in phosphorus and nitrogen delivery to the Gulf of Mexico from the Mississippi River basin: American Chemical Society, Environmental Science and Technology, v. 42, no.3, p. 822-830, available online.

Bachman, L.J., Lindsey, B.D., Brakebill, John, and Powers, D.S., 1998, Ground-water discharge to base-flow nitrate loads of nontidal streams and their relation to a hydrogeomorphic classification of the Chesapeake Bay Watershed, Middle Atlantic coast: U.S. Geological Survey Water –Resources Investigation Report 98-4059, 71p.

Brakebill, J.W., Ator, S.W., Schwarz, G.E., 2010. Sources of suspended-sediment flux in streams of the Chesapeake Bay watershed: A regional application of the SPARROW model. Journal of the American Water Resources Association 46(4) 757-776.

Breitburg D.L, Craig J.K, Fulford R.S, Rose K.A, Boynton WR, Brady D, Ciotti B.J, Diaz R.J, Friedland K.D, Hagy J.D III, Hart D.R, Hines A.H, Houde E.D, Kolesar S.E, Nixon S.W, Rice J.A, Secor D.H, Targett T.E. 2009. Nutrient enrichment and fisheries exploitation: interactive effects on estuarine living resources and their management. Hydrobiologia: 629: 31–47.

Bricker, S., B. Longstaff, W. Dennison, A. Jones, K. Boicourt, C. Wicks, and J. Woerner, 2007, Effects of Nutrient Enrichment in the Nation's Estuaries: A Decade of Change. NOAA Coastal Ocean Program Decision Analysis Series no. 26. National Centers for Coastal Ocean Science, Silver Spring, MD. 328 p. Available at: http

Collins, B.D., Kayen, R., 2006. Land-based Lidar mapping-a new surveying technique to shed light on rapid topographic change. U.S. Geological Survey Fact Sheet 2006-3111 4p.

Committee on Environment and Natural Resources, 2010 Scientific assessment of hypoxia in U.S. Coastal Waters, Interagency Working Group on Harmful Algal Blooms, Hypoxia, and Human Health of the Joint Subcommittee on Ocean Science and Technology, Washington D.C.

De Rose, R.C., Basher, L.R., 2011. Measurement of river bank and cliff erosion from sequential LIDAR and historical aerial photography. Geomorphology 126, 132-147.

Diaz, R.J., and Rosenberg, Rutger, 2008, Spreading dead zones and consequences for marine ecosystems, Science 321(5891) 926-929.

Diaz R.J, Schaffner, L.C., 1990, The functional role of estuarine benthos, pp. 25-56. In: M. Haire and E.C. Krome (eds.). Perspectives on the Chesapeake Bay, 1990. Advances in estuarine sciences. Chesapeake Research Consortium, Gloucester Pt., VA. Rpt. No. CBP/TRS41/90.

Dubrovsky, N.M., Burow, K.R., Clark, G.M., Gronberg, J.M., Hamilton P.A., Hitt, K.J., Mueller, D.K., Munn, M.D., Nolan, B.T., Puckett, L.J., Rupert, M.G., Short, T.M., Spahr, N.E., Sprague, L.A., and

Wilber, W.G., 2010, The quality of our Nation's waters—Nutrients in the Nation's streams and groundwater, 1992–2004: U.S. Geological Survey Circular 1350, 174 p.

Elser, James, and Bennett, Elena, 2011, Phosphorus: a broken biogeochemical cycle: Nature, v.478, p. 29-31, http://www.nature.com/nature/journal/v478/n7367/full/478029a.html.

Federal Interagency Panel on Climate Change and Water Data and Information, 2011, Report to Congress—Strengthening the scientific understanding of climate change impacts on freshwater resources of the United States, 49p.

Figley, W., Pyle, P., Halgren, B., 1979, Socioeconomic impacts. In: Oxygen depletion and associated benthic mortalities in New York Bight, 1976, R.L. Swanson and C.J. Sindermann (eds.), NOAA Professional Paper 11, pp. 315-322.

Gaither, Kelly, and Terry, D.L., 2004, Uniform fertilizer tonnage reporting system---version 4---instruction manual: Association of American Plant Food Control, 87p. available online at: http://www.aapfco.org/UFTRSDoc.pdf.

Galloway, J.N., Schlesinger, W.H., Levy, Hiram, II, Michaels, Anthony, and Schnoor, J.L., 1995, Nitrogen fixation: Anthropogenic enhancement-environmental response: Global Biogeochemical Cycles, v.9, no. 2, p. 235-252, accessed June 17, 2010, at: http://www.agu.org/journal/gb/v009/i002/95GB00158/95GB00158.pdf.

Gellis, A.C., and Walling, D.E., Sediment-source fingerprinting (tracing) and sediment budgets as tools in targeting river and watershed restoration programs: Simon A., Bennett, S.., Castro, J.M., eds., Stream Restoration in Dynamic Fluvial Systems: Scientific Approaches, Analyses, and Tools, American Geophysical Union Monograph Series 194, p. 263-291.

Gellis, A.C., Hupp, C.R., Pavich, M.J., Landwehr, J.M., Banks W.S.L., Hubbard, B.E., Langland, M.J., Ritchie, J.C., Reuter, J.M., 2009. Sources, transport, and storage of sediment in the Chesapeake Bay Watershed. U.S. Geological Survey Scientific Investigation Report 2008-5186, 95 p.

Gray, J.R., 2002. The need for sediment surrogate technologies to monitor fluvial-sediment transport. Proceedings of the Turbidity and Other Sediment Surrogates Workshop, Reno, NV, April 30 – May 2. Accessed at http://water.usgs.gov/osw/techniques/TSS/gray.pdf

Hirsch, R.M., Moyer, D.L., and Archfield, S.A., 2010, Weighted regression on time, discharge, and season (WRTDS) with an application to Chesapeake Bay River inputs, Journal of the American Water Resources Association, v. 46, no. 5, pp 857-880.

Horowitz, A.J., 1991, A primer on trace metal-sediment chemistry (2nd ed.): Ann Arbor, Michigan, Lewis Publ. Co., 136 p.

Howarth, R.W., 2008, Coastal nitrogen pollution: A review of sources and trends globally and regionally, Harmful Algae, 8: p 14-20.

Howarth, Robert, Anderson, Donald, Cloern, James, Elfring, Chris, Hopkinson, Charles, Lapoint, Brian, Malone, Tom, Marcus, Nancy, McGlathery, Karen, Sharpley, Andrew, and Walker, Dan, 2000, Nutrient pollution of coastal rivers, bays, and seas: Issues in Ecology, no. 7, accessed June 17, 2010, at http://www.epa.gov/watertrain/pdf/issue7./pdf.

Kinzel, P.J., Nelson, J.M., Wright, C.W., 2006. Monitoring changes in the Platte River riparian corridor with serial LIDAR surveys. U.S. Geological Survey Fact Sheet 2006-3063 4p.

Langendoen, E.J., Simon, A., Thomas, R.E, 2001. CONCEPTS- A process-based modeling tool to evaluate stream-corridor restoration designs. Proceedings from the 2001 Wetland Engineering & River Restoration Conference, Reno, Nevada, D.F. Hayes, ed., ASCE, Reston, VA, on CDROM.

Lawler, D.M., 1993, The measurement of river bank and lateral channel change: a review. Earth Surface Processes and Landforms 18, 777-821.

Lipton, D, and Hicks, R., 2003, The cost of stress: low dissolved oxygen and economic benefits of recreational striped bass (Morone saxatilis) fishing in the Patuxent River. Estuaries 26: 310-315.

Maupin, M.A., and Ivahnenko, Tammy, 2011, Nutrient loadings to streams of the continental United States from municipal and industrial effluent. Journal of the American Water Resources Association, v. 47, no. 5, p. 950-964, doi: 10.1111/j.1752-1688.2011.00576.x, http://onlinelibrary.wiley.com/doi/10.1111/j.1752-1688.2011.00576x/pdf

May E., 1973. Extensive oxygen depletion in Mobile Bay, Alabama. Limnology and Oceanography. 18: 353-366.

McKean, J., Isaak, D., Wright, W., 2009, Improving stream studies with a small-footprint green Lidar. EOS Transactions, American Geophysical Union, 90 (39) 341-342.

McMahon, P.B., Cowdery, T.K., Chapelle, F.H., and Jurgens, B.C., 2009, Redox conditions in selected principal aquifers of the United States: U.S. Geological Survey Fact Sheet 2009-3041, 6p, at http://pubs.usgs.gov/fs/2009/3041/pdf/FS09-3041.pdf.

National Center for Coastal Oceans Science, 2011, Harmful algal bloom and hypoxia research and control act, http://cop.noaa.gov/stressors/extremeevents/hab/habhrca/HABHRCA_fact.pdf

National Research Council, 2011, Letter report assessing the USGS National Water-Quality Assessment Program's Science Plan, Washington D.C., National Academy Press, 17p.

National Water Quality Monitoring Council, 2008, A national water quality monitoring network for U.S. coastal waters and their tributaries, available at: http://acwi.gov/monitoring/network/design/

Newell, W.L., Clark, I., 2008, Geomorphic map of Worcester County, Maryland, interpreted from a LIDAR-based, digital elevation model. U.S. Geological Survey Open-File Report 2008-1005, 34p.

Preston, S.D., Alexander, R.B., Schwarz, G.E., and Crawford, C.G., 2011, Factors affecting stream nutrient loads: A synthesis of regional SPARROW model results for the continental United States. Journal of the American Water Resources Association (JAWRA) 47 (5): 891-915, DOI: 10.1111/j.1752-1688.2011.00577.x, http://onlinelibrary.wiley.com/doi/10.1111/j.1752-1688.2011.00573.x/abstract.

Preston, S.D., Alexander, R.B., and Woodside, M.D., 2011, Regional assessments of the nation's water quality—improved understanding of stream nutrient sources through enhanced modeling capabilities, 6 p., available at http://pubs.usgs.gov/fs/2011/3114/.

Puckett, L. J., Tesoriero, A.J, and Dubrovsky, N.M., 2011, Nitrogen Contamination of Surficial Aquifer—A Growing Legacy: Environmental Science and Technology, v. 45, no. 3, p. 834-844, at http://pubs.acs.org/doi/abs/10.1021/es1038358.

Rabalais, N.N., and Turner, R.E., 2001, Coastal hypoxia, consequences for living resources and ecosystems. Coastal and Estuarine Studies, No 58, American Geophysical Union, Washington D.C., 463p.

Ribaudo, Marc, Delgado, Jorge, Hansen, LeRoy, Livingston, Michael, Mosheim, Roberto, and Williamson, James, 2011, Nitrogen in agricultural systems: implications for conservation policy. ERR-127, U.S. Dept. of Agriculture, Economic Research Service, 82p. Available at: http://www.ers.usda.gov/Publications/ERR127/ERR127.pdf.

Robertson, D. M, and D. A. Saad, 2011, Nutrient Inputs to the Laurentian Great Lakes by Source and Watershed Estimated Using SPARROW Watershed Models: Journal of the American Water Resources Association, vol. 47, no. 5, p. 1011-1033, DOI: 10.1111/j.1752-1688.2011.00574.x. Available at http://onlinelibrary.wiley.com/doi/10.1111/j.1752-1688.2011.00574.x/abstract.

Ruddy, B.C., Lorenz, D.L., and Mueller, D.K., 2006, County-level estimates of nutrient inputs to the land surface of the conterminous United States, 1982-2001: U.S. Geological Survey Scientific Investigations Report 2006-5012, 17p Available at: http://pubs.usgs.gov/sir/2006/5012/.

Saad, D.A., Schwarz, G.E., Robertson, D.M., and Booth, N.L., 2011, A multi-agency nutrient dataset used to estimate loads, improve monitoring design, and calibrate regional SPARROW models. Journal of the American Water Resources Association, v. 47, no. 5, p. 933-949.

Sanford, W.E., and Pope, J.P., 2007, A simulation of groundwater discharge and nitrate delivery to Chesapeake Bay from groundwater-seawater interactions, (eds.) Sanford, W., Langevin, C., Polemio, M., and Povinec. P., IAHS Publication 312, Oxfordshire, United Kingdom, p. 326-333.

Schwarz, G.E., Hoos, A.B., Alexander, R.B., and Smith, R.A., 2006, The SPARROW surface water-quality model—theory, application, and user documentation. U.S. Geological Survey Techniques and Methods 6-B3, 248p.

Schwarz, G.E., 2008. A preliminary SPARROW model of suspended sediment for the conterminous United States. U.S. Geological Survey Open-File Report 2008-1205 8p.

Selman, M., S. Greenhalgh, E. Branosky, C. Jones, and G. Guiling, 2009, Water Quality Trading Programs: An International Overview, World Resources Institute, Washington D.C.

Simon, A., Rinaldi, M., 2006. Disturbance, stream incision, and channel evolution: The roles of excess transport capacity and boundary material in controlling channel response. Geomorphology 79, 361-383.

Simon, A., Bankhead, N.L., Thomas, R.E. 2011. Development and application of a deterministic bank-stability and toe-erosion model (BSTEM) for stream restoration. In: Stream Restoration in Dynamics Fluvial Systems: Scientific Approaches, Analyses and Tools. American Geophysical Union. Geophysical Monograph Series. 194:500.

Sklash, M.G., and Farvolden, R.N., 1979, The role of groundwater in storm runoff. Journal of hydrology, v.43 no.1-4, p. 45-65.

Smith, R.A., Schwarz, G.E., and Alexander, R.A., 2008, Cost-efficient interstate management of nitrogen enrichment of rivers, streams and coastal waters, Poster: American Geophysical Union.

Spahr, N.E., Dubrovsky, N.M., Gronberg, J.M., Franke, O.L., and Wolock, D.M., 2010, Nitrate loads and concentrations in surface-water base flow and shallow groundwater for selected basins in the United States, water years, 1990– 2006: U.S. Geological Survey Scientific Investigations Report 2010–5098, 39 p.

Sprague, L.A., Hirsch, R.M., and Aulenbach, B.T., 2011, Nitrate in the Mississippi River and its tributaries, 1980-2008: Are we making progress? Environmental Science and Technology, v. 45, no 7, p. 7209-7216.

Subcommittee on Groundwater, 2009, A national framework for groundwater monitoring in the United States: Advisory Committee on Water Information, 74p. Available at:

Thoma, D.P., Gupta, S.C., Bauer, M.E., Kirchoff, C.E., 2005. Airborne laser scanning for riverbank erosion assessment. Remote Sensing of Environment 95, 493-501.

Townsend, A.R., and others, 2003, Human health effects of a changing global nitrogen cycle: Frontiers in Ecology and the Environment, v. 1, no. 5, p. 240-246, doi: 10.1890/1540-9295(2003)001[0240: HHEOAC] 2.0CO; 2, at: http://www.esajournals.org/doi/abs/10.1890/1540-9295%282003%29001%5B0240%3AHHEOAC%5D2.0.CO%3B2

Trimble, S.W., 1997. Contribution of stream channel erosion to sediment yield from an urbanizing watershed. Science 278, p.1442-1444.

Trimble, S.W., 2008, The use of historical data and artifacts in geomorphology, Progress in Physical Geography 32(1) p 3-29.

U.S. Department of Agriculture, 2006, Economic Research Service, Data Sets, U.S. Fertilizer Use and Price, last updated: September 25, 2006, Downloaded April 30, 2007 http://www.ers.usda.gov/Data/FertilizerUse/

U.S. Department of Agriculture, Natural Resources Conservation Service, Conservation Effects Assessment Project (CEAP), 2011, Assessment of the effects of conservation practices on cultivated cropland in the Chesapeake Bay region, 158p. accessed at: http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1042076.pdf.

U.S. Environmental Protection Agency, 2002, Summary table for the nutrient criteria documents: U.S. Environmental Protection Agency, Office of Water, 3 p., accessed June 17, 2010, at http://www.epa.gov/waterscience/criteria/nutrient /ecoregions/files/sumtable.pdf.

U.S. Environmental Protection Agency, 2003, Final water quality trading policy, Office of Water

U.S. Environmental Protection Agency, 2006, Wadeable streams assessment. EPA 841-B-06-002, pp. 1-98.

U.S. Environmental Protection Agency, 2008, Hypoxia in the Northern Gulf of Mexico: An Update by the EPA Science Advisory Board: EPA-SAB-08-003, 333 p., at http://yosemite.epa.gov/sab/sabproduct.nsf/C3D2F27094E03F90852573B800601D93/$File/EPA-SAB-08-003complete.unsigned.pdf

U.S. Environmental Protection Agency, 2009, An urgent call to action—Report of the State EPA Nutrient Innovations Task Group, accessed June 17, 2010, at: http://www.epa.gov/water science/criteria/nutrient/nitgreport.pdf.

U.S. Environmental Protection Agency, 2009, National Water Quality Inventory—Report to Congress, 2004 reporting cycle: U.S. Environmental Protection Agency, Office of Water, EPA-SAB-11-013, August, 2011841-R-08-001, 37 p., accessed June 17, 2010 at: http://www.epa.gov/305b/2004report/2004_305Breport.pdf.

(USEPA, 2010. *National Lakes Assessment: A Collaborative Survey of the Nation's Lakes,* EPA 841-R-09-001, USEPA Office of Water and Office of Research and Development, Washington DC, April 2010).

U.S. Environmental Protection Agency, 2011a, Reactive nitrogen in the United States: An analysis of inputs, flows, consequences, and management options—A report of the EPA Science Advisory Board: EPA841-R-08-001, 172 p., at: http://yosemite.epa.gov/sab/sabproduct.nsf/67057225CC780623852578F10059533D/$File/EPA-SAB-11-013-unsigned.pdf.

U.S. Environmental Protection Agency, 2011b, Detroit River-Western Lake Erie Basin Indicator Project, accessed November, 15, 2001, at: http://www.epa.gov/med/grosseile_site/indicators/algae-blooms.html.

U.S. Environmental Protection Agency, 2011c, National summary of state information, available at: http://iaspub.epa.gov/waters10/attaiins_nation_cy.control.

U.S. Geological Survey, 2011a, NASQAN-National Stream Quality Accounting Network, available at: http://water.usgs.gov.nasqan/.

U.S. Geological Survey 2011b, Status of MODFLOW versions and MODFLOW-related programs available on USGS web pages, available at: http://water.usgs.gov/nrp/gwsoftware/modflow-status-2011Jan.pdf.

U.S. Government Accountability Office, 2004, Watershed management—Better coordination of data collection efforts needed to support key decisions, Washington D.C. , Report GAO-04-382, 155p.

Van Metre, P. C., and Mahler, B.J., 2005, Trends in hydrophobic organic contaminants in urban and reference lake sediments across the United States, 1970-2001: Environmental Science and Technology, v. 39, 5567-5574.

Vitousek, P.M., Aber, J.D., Howarth, R.W., Likens, G.E., Matson, P.A., Schindler, D.W., Schlesinger, W.H., and Tilman, D.G., 1997, Human alteration of the global nitrogen cycle: sources and consequences: Ecological Applications, v. 7, issue 3, p. 737-750, accessed June 17, 2010 at: http://www.esajournals.org/doi/abs/10.1890/1051-0761(1997)007%5B0737:HA0TGN%5D2.0.CO%3B2.

Walbridge, M.R., and Shafer, S.R. 2011, A long-term Agro-Ecosystem Research (LTAR) Network for Agriculture, Fourth Interagency Conference on Research in Watersheds, September 26-30, 2011, Fairbanks, AK, 4p.

Walling, D.E., Owens, P.N., Graham, J., Leeks, L., 1999. Fingerprinting suspended sediment sources in the catchment of the River Ouse, Yorkshire, UK. Hydrological Processes 13, 955-975.

Walling, D.E., 2005. Tracing suspended sediment sources in catchments and river systems. Science of the Total Environment 344 (1-3) 159-184.

Ward, M.H., deKok, T.M., Levallois, P., Brender, J., Gulis, G., Nolan, B.T., and Vandeslice, J., 2005, Drinking water nitrate and health—Recent findings and research needs: Environmental Health Perspectives, v. 113, no. 11, p. 1607-1614, doi:10.1289/ehp.8043, at: http://ehp03.niehs.nig.gov/article/info%Adoi%2F10.1289%2Fehp.8043.

Senator CARDIN. Thank you very much for your testimony.
Ms. Stoner.

STATEMENT OF NANCY STONER, ACTING ASSISTANT ADMINISTRATOR FOR WATER, U.S. ENVIRONMENTAL PROTECTION AGENCY

Ms. STONER. Good afternoon, Chairman Cardin, Ranking Member Sessions and members of the Committee and Subcommittee.

I am Nancy Stoner, Acting Assistant Administrator for Water at USEPA. I am pleased to be here this afternoon alongside Chief White of NRCS and Associate Director Werkheiser of USGS to discuss the agency's efforts to protect public health and the environment in the context of nutrient pollution, one of the Nation's most pervasive water quality problems.

Nutrient pollution has become one of the most widespread, costly and serious water pollution challenges being faced by communities across the Country. Nutrients such as nitrogen and phosphorus pollute the waterways in which our families fish and swim, contaminate our drinking water supplies and cause illness and choke the economic health of businesses across the Nation that rely on clean and safe water.

Abundant sources of clean and safe water are vital for healthy communities, ecosystems and businesses in America. Clean water is not simply a resource and asset to be passed along to our children. It is an essential part of everyday life. Clean water is an essential component of public health, our drinking water supplies and the welfare of our families and communities, whether in large cities, small towns or rural America.

The economic health and growth of businesses large and small, and the jobs they create, rely upon a high quality and reliable source of clean water. The range of businesses that depend on our water resources include tourism, farming, fishing, beverage production, manufacturing, transportation and energy generation, just to mention a few.

Nutrient pollution contributes to significant impacts to our Nation's economy and the health of our communities. Let me provide a few examples. In Oregon, the State's health authority reports that 18 lakes and reservoirs were affected by harmful algal blooms caused by high nutrient levels, leading to nine closures in 2011. Additional closures remain in effect today.

The Kansas Department of Health and the Environment has issued public health advisories for four lakes, warning residents that the water is unsafe for human or animal consumption and contact due to harmful algal blooms. Eight additional Kansas lakes have public health warnings that advise no contact with the water.

Algal bloom toxins have been found in the Kansas River, a major drinking water source for nearly 60,000 residents in eastern Kansas. In Oklahoma, blue green algal blooms that started to develop before the Fourth of July continue to affect seven lakes in the State and beaches at four lakes remain closed.

In Ohio, Grand Lake St. Mary's has received national attention for massive algal blooms that have led to the deaths of fish, birds, dogs and illnesses in at least seven people. These algal blooms and toxins have resulted in economic losses due to beach closures and lower tourism revenue, and have threatened drinking water supplies and public health.

In addition to the toxins associated with algal blooms, nutrient pollution itself can also pose a risk to the water we drink. High levels of nitrate in drinking water have been linked to serious illness in infants and other human health effects. Reported drinking water violations for nitrates have doubled nationwide in the last decade and some public water systems have had to install costly treatment systems to reduce nitrate levels.

Recognizing the need for a more coordinated effort to reduce nutrient pollution, the EPA has renewed its commitment to work with other Federal agencies, States and other stakeholders to achieve progress. EPA believes that States are best suited to take the lead in addressing nutrient pollution, and we work closely with our State and local partners to ad their efforts.

In March, I sent a memorandum to our regional offices, making it clear that reducing nitrogen and phosphorus pollution is best addressed by States relying on a range of regulatory and non-regulatory tools, including proven conservation practices. We also appreciate the significant leadership demonstrated by USDA and USGS on this important issue.

The EPA works closely with USDA, USGS and States to monitor the extent and impact of nutrient pollution and implement nutrient reduction projects on the ground. In addition, to complement the efforts of USDA and other partners, we are focusing on broader efforts to use funding under Section 319 of the Clean Water Act for watershed planning and stakeholder involvement.

Working closely with USDA, we are engaging creatively in work with communities to achieve improvements in water quality. We are also partnering with USDA, the Department of Interior, and Chesapeake Bay States to implement the landmark Chesapeake Bay total maximum daily load, which is a pollution diet for nutrients in the Bay.

In conclusion, Mr. Chairman, the threat posed by nutrients in our Nation's waters is one of the most serious water pollution problems faced by our communities nationwide. We at the EPA are committed to working with States, other Federal agencies, farmers, business, communities and other stakeholders to identify ways to tackle the nutrient pollution problem in a way that protects our Nation's waters, sustains our economy and safeguards the health and well-being of all Americans who depend upon clean and safe water. We look forward to working with the Subcommittee as these efforts proceed.

Thank you for the opportunity to testify before you today. I look forward to answering any questions you may have.

[The prepared statement of Ms. Stoner follows:]

TESTIMONY OF

NANCY K. STONER
ACTING ASSISTANT ADMINISTRATOR FOR WATER
U.S. ENVIRONMENTAL PROTECTION AGENCY

BEFORE THE
SUBCOMMITTEE ON WATER AND WILDLIFE
COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS
UNITED STATES SENATE

October 4, 2011

Good morning Chairman Cardin, Ranking Member Sessions, and Members of the Subcommittee. I am pleased to appear before you today to discuss the EPA's mission to protect public health and the environment in the context of the water quality challenges from what is known as "nutrient pollution." This pollution, which comes from high levels of nitrogen and phosphorus, threatens the quality of the Nation's waters and the prosperity of communities across the country. This urgent problem requires effective collaboration at the federal, state, and local levels to address the growing environmental and public health risk and its economic impacts.

I am pleased that Chief White of the Natural Resources Conservation Service (NRCS) and Associate Director Werkheiser of the U.S. Geological Survey (USGS) are also testifying with me today. NRCS and USGS deliver important programs and scientific expertise that play critical roles in protecting the quality of our waters and addressing nutrient pollution.

My objective today is to provide the Subcommittee with our understanding of the problem of nutrient pollution, including the contributions from various sources, as well as the various approaches and tools that the EPA, other federal agencies, states, regulated entities, and others have employed – working together – to address this critical problem.

We all recognize the value of clean water. Clean water is not simply a resource and asset to be passed on to our children; it is an essential part of life. Clean water is essential to public health, drinking water supplies, quality of life, and the welfare of families and communities, whether in large cities, small towns, or rural America. The health and growth of small and large businesses and the jobs they create rely upon a high quality and sustainable source of water. The range of businesses that depend on a reliable and plentiful supply of clean water include tourism, farming, fishing, beverage production, manufacturing, transportation, and energy generation, just to mention a few.

Extent of the Nutrient Pollution Problem

Nitrogen and phosphorus pollution is a major threat to clean water. This has been extensively documented in the scientific literature and confirmed by monitoring data collected at federal, state, and local levels. States have identified more than 15,000 waters nationwide that have been degraded by excess levels of nutrients to the point that they do not meet state water quality standards. The EPA's most recent National Aquatic Resource Surveys of aquatic health found that of the stressors assessed, nitrogen and phosphorus are the most pervasive in the Nation's small streams and lakes. Approximately 50 percent of streams and more than 40 percent of lake acres have high or medium levels of nutrients.

Contamination of coastal waters by nutrient pollution is also a widespread and growing problem. For example, a recent analysis of 647 U.S. coastal and estuarine ecosystems indicates that the percentage of systems with low oxygen levels or hypoxia (a common result of high nutrient levels) has increased dramatically since the 1960s and has become measurably worse even since the 1980s. The first national assessment of oxygen conditions in U.S. waters, conducted in the 1980s, found 38 percent of systems to have hypoxia. Updating the information using today's data finds that 307 of 647 ecosystems, or 47 percent, experience hypoxic conditions. Severe hypoxia can result in "dead zones," an occurrence that unfortunately is occurring in increasing scope and magnitude in many of the Nation's coastal waters.

An increasingly widespread and persistent result of nutrient pollution is the proliferation of harmful algal blooms – a situation in which waters are choked with algae and green with slime. Moreover, some harmful algal blooms produce toxins that threaten public health, aquatic life, food sources, and drinking water quality. Because of the increased incidence of these and other risks, many states actively monitor their waters for harmful algal blooms to protect swimmers, assure safe recreational uses, and protect consumers of shellfish. Some states, for example Kansas, Ohio, and New York, have public websites to post advisories warning citizens about the dangers of public waters that are impacted by harmful algal blooms.

During the summer of 2011, communities across the country were affected by harmful algal blooms in their waters:

- In Oregon, the state's health authority reports that 18 lakes and reservoirs affected by cyanobacteria led to nine closures that lasted from 11 to 62 days during the vital summer months. Additional closures remain in effect today;
- The Kansas Department of Health and Environment has issued public health advisories for four lakes, warning residents that the water is unsafe for human or animal consumption and contact due to cyanobacteria. Eight additional Kansas lakes have public health warnings that advise no contact with the water;
- The Associated Press reported on September 21 that low levels of cyanobacterial toxins have been detected in the Kansas River, a major drinking water source for nearly 60,000 residents in eastern Kansas, prompting studies on the potential effects of the toxins on people and the local environment;
- In Oklahoma, cyanobacterial blooms that started to develop before the Fourth of July continue to affect seven lakes in the state. Beaches at four lakes remain closed, while six lakes have advisories discouraging swimming and other recreation on the water;
- In Ohio, Grand Lake St. Marys has received national attention for massive algal blooms that have led to deaths of fish, birds, dogs, and illnesses in at least seven people. These blooms have resulted in widespread economic losses due to beach closure and lower tourism revenue, and have threatened an important drinking water source for about 10,000 people. The public health advisory for the lake that was issued in May was just lifted after four months, according to the Ohio Environmental Protection Agency; and
- Additional toxic algal blooms have been reported in fresh waters in the State of Washington and the Great Lakes, while marine harmful algal blooms have been reported in Florida and Massachusetts.

Nutrient pollution can also affect the water that we drink. Levels of nitrate (a compound of nitrogen) in drinking water above the federal drinking water standard of 10 milligrams per liter have been linked to serious illness in infants, as well as other potential human health effects. Reported violations for nitrate standards at public water systems have doubled in the last eight years, with more than 1,000 violations in 2010. In the face of high nitrate levels, water systems have had to install treatment in order to remain in compliance. For example, in Lancaster County, Pennsylvania, more than 140 surface and groundwater systems have had to invest in new technology such as ion exchange treatment in order to clean up nitrate contamination and protect public health. The City of Fremont, Ohio is building a new $15 million drinking water reservoir in response to high nitrate levels in the Sandusky River.

Nitrate can also be a risk to the 15 percent of Americans that use private wells that are not regulated under the Safe Drinking Water Act. Just this past year, USGS published a report that found nitrate levels in groundwater to exceed the federal drinking water standard of 10 mg/L in more than 20 percent of the shallow (less than 100 feet below the land surface) private water wells in the agricultural areas that it tested. This raises a potential concern for people in rural areas who rely on shallow wells for their water supply because of the potential for nitrate contamination. Although most public water systems that use groundwater sources get their water from deeper wells, USGS advises that nitrate may become a concern even for these systems, as surface pollution infiltrates and could contaminate deeper municipal drinking water supply aquifers.

In addition to the well-documented relationship between high nitrate levels and increased risk of serious illness in infants, nutrients can contribute to drinking water contamination in other ways. For example, toxins released by harmful algal blooms caused by high nutrient levels can pose risks to public health and aquatic communities. When not properly treated, the ingestion of water contaminated with these toxins can have health impacts on the liver, kidney, or nervous system. Additionally, higher levels of algae caused by nutrients in drinking water sources can increase the formation of byproducts from disinfection processes used at drinking water facilities. Exposure to disinfection byproducts can pose public health risks, due to their potential carcinogenicity and possible reproductive and developmental health risks. Removing these contaminants once they are formed can be expensive. The best way to address these byproducts is to prevent their formation in the first place.

Contributions from Various Sectors

The sources of nitrogen and phosphorus pollution to a waterbody depend on activities surrounding and upstream of a particular waterbody. In general, the primary sources of nitrogen and phosphorus pollution in urban and suburban areas are stormwater runoff and municipal wastewater treatment systems. In rural areas, towns and cities continue to be an important contributor, but the predominant sources are waste from agricultural livestock activities and excess fertilizer from row crops.

Stormwater : Stormwater can collect fertilizers and other applied nutrients, as well as other pollutants on impervious surfaces, before it is discharged to receiving waters. While urban stormwater may have lower nutrient concentrations than other nonpoint sources of pollution, urban watersheds produce a much larger annual volume of runoff, such that the mass of nutrient pollution generated from stormwater can be significant.

Wastewater Treatment Systems: U.S. municipal wastewater treatment facilities currently treat about 34 billion gallons of wastewater per day. Depending on the local ecological conditions and their relative contribution, discharges from publicly owned treatment works (or POTWs) can be a significant source of nutrients. POTWs receive permits under the Clean Water Act to reflect both technology-based secondary treatment requirements and applicable water quality standards. Onsite and decentralized wastewater treatment systems (or septic systems) are used in approximately 20 percent of U.S. homes and can also be a significant contributor to nutrient pollution.

Livestock Waste: Animal agriculture production results in the generation of more than 1 billion tons of manure each year, resulting in more than 8 million pounds per day of nitrogen and 3 million pounds per day of phosphorus.[1] Much of the manure is applied to farmland as fertilizer for crops. If done appropriately using the four "R's" – right rate, timing, method, and form – nutrients are applied so that they can be taken up by crops, and water quality impacts are minimized. However, if applied without considering the four R's, this manure may enter nearby waters and thereby contribute to nutrient pollution. Large feedlots and dairies (referred to as Concentrated Animal Feeding Operations) are required to obtain a Clean Water Act permit if they discharge pollutants, including nutrients, to waters of the United States. Smaller livestock production

[1] "An Urgent Call to Action: Report of the State-EPA Nutrient Innovations Task Group." 2009. Available at http://water.epa.gov/scitech/swguidance/standards/criteria/nutrients/upload/2009_08_27_criteria_nutrient_nitgreport.pdf

activities are generally unregulated under the Clean Water Act. EPA and USDA have been working for many years to provide both funding and technical assistance to help farmers better manage their manure, with some success.

Row Crop Fertilizer: Row crop agriculture can contribute nutrients when fertilizer in either manure or chemical forms is applied to but not taken up by crops. Even when fertilizers are applied at appropriate rates, the typical nitrogen utilization by crops is less than 30 percent. A USDA report published two weeks ago notes that reducing nitrogen application rates is the most effective way to reduce reactive nitrogen and that opportunities exist for achieving additional nutrient reductions.[2] The nutrients not used by crops can volatilize into the air, infiltrate into groundwater or run off the land with stormwater, adding to the problem of nutrient overabundance in the aquatic environment.

Air Deposition: Nationwide, the deposition of nitrogen oxide compounds released to the air during fossil fuel combustion contributes significant inputs of additional nitrogen to the land and surface water. Cars and other mobile sources account for about 55 percent of nitrogen oxide emissions, while stationary sources account for the rest.

Actions to Address the Nutrient Pollution Problem

The EPA recognizes the nation's significant nutrient pollution challenges and is committed to finding collaborative solutions that protect and restore our waters and the health of the communities that depend on them. The growing and costly impacts of nutrient pollution on

[2] "Nitrogen in Agricultural Systems: Implications for Conservation Policy." 2011. Available at http://www.ers.usda.gov/Publications/ERR127/.

human health, recreation, tourism, business growth and expansion, and aquatic ecosystems demand a strengthened and far more coordinated framework of action if we are to succeed in the urgently needed job of reducing nitrogen and phosphorus loadings to our nation's waters.

To reaffirm the EPA's commitment to partner with states and collaborate with stakeholders to reduce nitrogen and phosphorus loadings to the Nation's waters, I sent a memorandum to the EPA's ten Regional offices in March of this year. The memo, entitled *Working in Partnership with States to Address Phosphorus and Nitrogen Pollution through Use of a Framework for State Nutrient Reductions*, lays out a framework for guiding the EPA's work with states and stakeholders to achieve nutrient reductions. The EPA recognizes that states need room to innovate and respond to local water quality needs, and that a one-size-fits-all solution to nitrogen and phosphorus pollution is neither desirable nor necessary.

The EPA believes that the most important tool within an effective state nutrient reduction framework is the development of a statewide list of prioritized watersheds to target the efforts of states and stakeholders to specific watersheds that account for a substantial portion of the nutrient pollution load. Within these watersheds, we can work together to develop stronger permits for point sources, and where appropriate, reduction measures for nonpoint sources, and opportunities to reduce discharges from unregulated stormwater point sources. Our Clean Water Act experience has shown that motivated states, using available tools and high-quality science, can mobilize local governments and stakeholders to achieve significant results. Federal agencies, such as NRCS, play an important role in promoting management practices that can protect and restore waters in these priorities watershed and other areas.

In addition to the significant benefits provided by state watershed targeting, numeric nutrient criteria targeted at different categories of water bodies and informed by scientific understanding of the relationship between nutrient loadings and water quality impairment, are effective and practical tools for the EPA and states to tackle the nutrient pollution problem. The EPA has worked with 25 states across the country to develop and approve numeric nutrient criteria for at least some of their waters, and continues to support and collaborate with others to achieve our common goals.

Once effective watershed plans and nutrient standards are in place, the EPA, states, and stakeholders can work within the existing Clean Water Act framework to identify opportunities for achieving nutrient reductions and take action. Nutrient reductions for point sources of pollution can be achieved through National Pollutant Discharge Elimination System (NPDES) permits, which can be written to include permit limits that result in reduced nutrient discharges to affected waterbodies and therefore healthier waters.

For discharges to waters that states have determined are impaired as a result of nutrient pollution, Total Maximum Daily Loads (TMDLs) provide loading limits for point and non-point sources that, when implemented, will achieve water quality standards. Moreover, in conjunction with USDA and several states, the EPA is exploring "certainty" mechanisms that encourage farmers who are not required to be permitted under the federal Clean Water Act to implement voluntary practices that reduce impacts on water quality and thereby increase the pace and extent to which resource conservation and verifiable water quality improvements are achieved. Under such a framework, in exchange, the farmer would receive assurances that her actions are consistent with state plans to improve water quality.

Another approach with significant potential is water quality trading, which can provide cost-effective reductions in nutrient loadings within a watershed. Sources that achieve greater-than-required nutrient reductions can receive "credits" that can be traded to other sources that cannot as easily reduce nutrient loadings. Trading can occur between point sources, or between point and non-point sources, which are then usually implemented through permits. The EPA has developed a toolkit for water quality trading that can help identify possible approaches that states, the regulated community, and other sources can use to encourage water quality trading.[3]

For nonpoint sources, states, territories and authorized tribes can receive grants under CWA Section 319 Nonpoint Source Management Program to support a wide variety of activities including technical assistance, financial assistance, education, training, technology transfer, state regulatory programs that prevent or reduce nonpoint source pollution, demonstration projects, and monitoring to assess the success of specific nonpoint source implementation projects. The program relies on both state-wide Nonpoint Source Management Programs and the development and implementation of watershed plans to effectively reduce pollution. The effectiveness of watershed plans depends on the comprehensiveness of the plan, the management of the grant funds, and how completely the plan is implemented. States and other recipients of Section 319 grants often leverage their grants with resources from other funding sources, such as cost share funding from USDA, and find the broad range of eligible activities under Section 319 to be

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[3] The EPA's Water Quality Trading Toolkit for Permit Writers is available at http://water.epa.gov/type/watersheds/trading/WQTToolkit.cfm.

essential for developing and completing effective projects. The Farm Bill also includes funding for a variety of conservation programs, including the Environmental Quality Incentives Program, which offers financial and technical assistance to eligible participants to help plan and implement structural and management conservation practices that address natural resource concerns and offer opportunities to improve soil, water, plant, animal, air and related resources on eligible agricultural land and non-industrial private forestland.

Tools known as Best Management Practices (BMPs) can also be an effective mechanism for reducing nutrient pollution from agriculture, urban stormwater, and other sources. BMPs are effective controls or other practical actions that can be used to mitigate pollution. BMPs are implemented for a variety of purposes, including protecting water resources, human health, terrestrial or aquatic wildlife habitat, and land from degradation by wind, salt, and toxic levels of metals. The primary focus of many BMPs is to reduce the delivery of pollutants into water resources by reducing pollutant generation or by remediating or intercepting pollutants before they enter water resources. These BMPs can be useful in a variety of sectors:

> Agriculture: Effective BMPs to control the delivery of nutrients and sediment from agricultural operations can be implemented by a systems-based, site-specific nutrient management planning approach. Evidence shows that these practices are most effective when implemented as a coordinated suite of practices.[4] Available tools include nutrient source control and avoidance (right rate, timing, form and method of application), in-field control, and edge-of-field trapping and treatment. The optimization of agricultural

[4] See USDA/NRCS report, "Assessment of the Effects of Conservation Practices on Cultivated Cropland in the Upper Mississippi River Basin," available at http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1042093.pdf.

fertilizer application can also reduce the amount of nutrients added and limit runoff, thereby helping to reduce nutrient pollution. Reducing fertilizer application can also help a farmer's bottom line.

Stormwater: Hydrology can be a critical driver of water quality impairments in developed and developing areas. Thus, managing runoff to minimize the mobilization and discharge of pollutants is an important component of limiting nutrient pollution from these areas. Implementing BMPs that employ low impact development (LID) and other green infrastructure techniques allows infiltration, evapo-transpiration, and the use of rainwater on-site. Also, grasses or turf can contribute a substantial amount of nutrients from suburban lands, and landowners can employ BMPs to control the losses. Bans or reductions of phosphate in detergents, other cleaning products, and lawn fertilizers can also reduce nutrient pollution from urban areas.

Decentralized Wastewater Treatment: Nitrogen pollution from decentralized wastewater treatment systems can be effectively controlled when cluster treatment systems are implemented to treat effluent from multiple lots at nearby off-site locations, or advanced single-family home systems that reduce nutrient concentrations are installed.

Geographic Initiatives

The EPA is strongly committed to addressing the problem of nutrient pollution and doing so in collaboration with states, tribes and other federal agencies. In addition to the EPA's nationwide efforts to address the nutrient pollution problem, the EPA is also working closely with its partners in specific geographic areas, including working with states whose waters flow to the Chesapeake Bay, Long Island Sound, the Great Lakes, Lake Champlain, and the Gulf of Mexico. As an example, the EPA is working hard to focus on water quality goals in the Mississippi and Atchafalaya River Basin. The EPA is working with USDA, USGS, and states to provide monitoring support in a subset of USDA's Mississippi River Basin Initiative watersheds. To complement the efforts of USDA and other partners, we are focusing on broader efforts to use funding under Section 319 of the Clean Water Act for watershed planning and stakeholder involvement to enhance USDA programs by engaging creatively in work with communities and watersheds to achieve improvements in water quality. The EPA also serves as co-chair of the Gulf Hypoxia Task Force, which provides a forum for 17 state and federal agencies – including USDA and the Department of the Interior – to partner on efforts to mitigate nutrient loadings and encourage a holistic, cooperative approach. The EPA looks forward to our continued work with Chief White, Associate Director Werkheiser, and their colleagues in this effort.

Additionally, the EPA has engaged states and stakeholders to partner in addressing nitrogen and phosphorus pollution on numerous fronts. In 2009, the EPA helped to lead the nationally focused State-EPA Nutrient Innovations Task Group to evaluate the science, sources, and economic impacts behind the ongoing problem of nutrient pollution and to develop recommendations for controlling the impacts to our nation's drinking water supplies and waterways. The Task Group issued *An Urgent Call to Action*, which provides specific recommendations to the EPA Administrator and the public for joint state and federal actions to control nitrogen and phosphorus pollution.[5] The EPA, other federal agencies and the states are also collaborating on the Gulf Restoration Initiative and several joint committees with the Association of Clean Water Administrators, the Association of State Drinking Water Administrators, and the National Association of Clean Water Agencies. Finally, EPA is working closely with USDA, the Department of the Interior, and Chesapeake Bay states to implement the landmark Chesapeake Bay TMDL, which sets a pollution diet for nutrients in the Bay.

Conclusion

The threat posed by nutrients in the Nation's waters is one of the most serious water pollution problems faced by the EPA, the states, and local communities. The EPA is committed to working with our partners at USGS and NRCS, as well as states, other federal agencies, farmers, businesses, communities, and other stakeholders to identify ways to tackle the nutrient problem in a way that protects waters, sustains the economy, and safeguards the well-being of all Americans who depend upon clean and safe water.

Thank you for the opportunity to testify before the Subcommittee today. I look forward to answering any questions you may have.

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[5] The Task Group's report is available at
http://water.epa.gov/scitech/swguidance/standards/criteria/nutrients/upload/2009_08_27_criteria_nutrient_nitgreport.pdf

Enclosure
Responses to Questions for the Record
Subcommittee on Water and Wildlife
Committee on Environment and Public Works
Hearing on "Nutrient Pollution: An Overview of Nutrient Reduction Approaches"
October 4, 2011

Senator Barbara Boxer

1. **Isn't it true that the Bush Administration EPA, the EPA Inspector General, the National Academies of Science, and a State-EPA nutrient task force led by the Association of State and Interstate Water Pollution Control Administrators (ASIWPCA) and the Association of State Drinking Water Administrators (ASDWA) all highlighted the benefits of using numeric nutrient criteria?**

   Given that multiple independent bodies, including bodies representing state pollution control and drinking water agencies, recommended the use of numeric nutrient criteria, isn't it appropriate for EPA to consider how to incorporate these standards into its ongoing efforts to reduce nutrient pollution?

Yes, it is true that all those entities have highlighted the benefits of using numeric nutrient criteria. The EPA has been recommending that states adopt numeric nutrient criteria since our 1998 National Strategy for the Development of Regional Nutrient Criteria and believes it is appropriate to consider how to incorporate numeric criteria into ongoing efforts to reduce nutrient pollution.

Under the Clean Water Act, primary responsibility for the development and implementation of water quality standards rests with the states. On March 16, 2011, the EPA released a memorandum entitled "Working in Partnership with States to Address Phosphorus and Nitrogen Pollution through Use of a Framework for State Nutrient Reductions" (Framework Memo). The Framework Memo places a strong emphasis on working with states to achieve near-term reductions in nutrient loadings. The Framework Memo includes recommended elements of a state nutrient reduction strategy as a tool to guide ongoing collaboration between the EPA and states and among federal, state, and local partners in our joint effort to make progress on reducing nitrogen and phosphorous pollution. Development of numeric nutrient criteria is one aspect of this coordinated and comprehensive approach. The EPA is committed to and engaged in providing to states the most current scientific information and technical resources to develop numeric nutrient criteria and strengthen their underlying rationale and defensibility.

2. **Does the use of numeric nutrient criteria imply the use of a single nation-wide or state-wide standard? Can numeric nutrient criteria be used in a flexible manner that adapts to local conditions?**

The use of numeric nutrient criteria does not imply the use of a single nationwide or state-wide standard. The EPA does not believe that setting uniform nationwide numeric nutrient standards would be appropriate because it would not reflect the multiplicity of different ecosystems across the country and the differing ways in which nutrient levels may affect these ecosystems. Even statewide standards are likely to require different criteria for different ecoregions within the state, as well as some site-specific flexibility. Numeric nutrient criteria can be used in a flexible manner that adapts to local conditions. Where the EPA has made recommendations regarding nutrient criteria for lakes, reservoirs, rivers, and streams, the EPA has done so based on nutrient ecoregions, which are regions of relative homogeneity in ecological systems, recognizing that states can develop more refined criteria. In addition to site-specific criteria, states have adopted nutrient criteria for subcategories of lakes and rivers, often by ecoregion within the state.

The EPA strongly believes that states are best suited to address nutrient pollution. The EPA recognizes that states need flexibility to develop creative and cost-effective solutions for addressing nitrogen and phosphorus pollution and that a one-size-fits-all solution is neither desirable nor necessary. The EPA continues to prefer that states develop numeric nutrient criteria for their waters, and the EPA stands ready to work with states to tailor a nutrient reduction approach to particular state circumstances. The EPA is interested in continuing to engage with states through workshops and webinars to share best practices and experiences and to develop innovative approaches to address nutrient pollution that are scientifically defensible and meet the requirements of the Clean Water Act.

3. **In an April 2010 letter providing comments on EPA's guidance on numeric nutrient criteria, the Science Advisory Board commended EPA for addressing nutrient issues, recognized the importance and legitimacy of efforts to develop numeric nutrient criteria, and provided suggestions for improving the guidance.**

   The SAB validated EPA's general approach while suggesting areas for improvement. Is EPA working to improve the guidance based on the SAB's recommendations so that it will be more useful for users?

In response to the Science Advisory Board (SAB)'s independent peer review of the EPA's draft guidance, the EPA revised its recommended nutrient criteria derivation methodologies and issued them in final form in late 2010.

The Science Advisory Board (SAB) reviewed the EPA draft technical support document, *Empirical Approaches for Numeric Nutrient Criteria Derivation,* and provided comments in an April 2010 letter in which the Board validated the EPA's overall approach while suggesting areas for improvement. Specifically, the SAB determined that the "stressor-response approach is a legitimate, scientifically based method for developing numeric nutrient criteria if the approach is appropriately applied." The critiques that the SAB provided were not on the approach itself, but rather on the detail provided in the technical support document to assist states in the use of this approach. The EPA further revised this document to address the SAB's concerns; namely, to present a more complete and balanced view of using statistical methods to develop the criteria to make the document more useful to state and tribal water quality scientists and resource managers. This revised technical support document, *Using Stressor-response Relationships to Derive Numeric Nutrient Criteria* (EPA-820-S-10-001), was released in final form in November

2010. The guidance document may be used by states as an additional tool to develop scientifically defensible numeric nutrient criteria.

In addition to the technical support that the EPA provides in the form of technical support documents on the methods and approaches available for deriving numeric nutrient criteria, the EPA provides expert technical assistance via a web-based clearinghouse for numeric nutrient criteria development (N-STEPS), and outreach in the form of workshops and technical meetings. The EPA will continue to partner with states, the scientific community, and all stakeholders on the development and implementation of numeric nutrient criteria.

Senator Max Baucus

1. **What specific steps is EPA Region 8 following to carry out Ms. Stoner's March 2011 directive to work with states to find innovative solutions to nutrient loading?**

Using the March 16, 2011 memo as a guide, EPA Regional Administrators, including Region 8 Administrator Jim Martin, have begun dialogues with states, tribes, and stakeholders. These dialogues have focused on how we can best work together to make near-term progress on reducing nitrogen and phosphorus pollution while states continue their efforts, which the EPA has encouraged since 1998, to develop numeric criteria for these pollutants. The March 16 memo builds on principles that the EPA has previously articulated and reaffirms the EPA's commitment to partnership with states and collaboration with stakeholders.

Within Region 8, the EPA has been working collaboratively with states to address nutrient pollution concerns. Activities include the following:

- Sponsoring a stakeholder workshop focused on developing an understanding of nutrient-related concerns and identifying possible solutions;
- Working with both Colorado and Montana to evaluate their respective approaches for addressing nutrients;
- Forming a regional workgroup to identify effective nutrient best management practices; and
- Finding innovative approaches that support adoption of numeric nutrient criteria by states, recognizing that progress may be incremental.

2. **In 2011, the state of Montana legislature overwhelmingly passed a bill (S.B. 367) on direct implementation of the state's numeric standards. What specific provision, if any, of current federal statute, regulation, or guidance would preclude full implementation of S.B. 367 in Montana?**

Montana's law, former Senate Bill 367, authorizes variances from numeric nutrient criteria based on economic hardship on dischargers. Variances are one tool available to states in situations where water quality standards cannot be met immediately, but where the state believes that the standard ultimately can be attained. Variances are temporary, subject to review every three years, and may be extended upon expiration. Generally, variances are an appropriate tool to consider where it can be demonstrated that it is not feasible to attain the designated use during the term of the proposed variance based on one of the factors specified in 40 CFR Section 131.10(g), such as substantial and widespread economic and social impacts. As a change to a state's water quality standards, a variance requires the EPA's review and approval before it becomes effective for Clean Water Act purposes (40 CFR Section 131.21(c)). A variance temporarily establishes a less stringent water quality standard that can be met with the expectation that the discharger will make feasible progress toward protecting the designated use.

As articulated in a January 3, 2012 letter from Region 8 Regional Administrator Jim Martin to Montana Department of Environmental Quality (DEQ) Director Richard Opper, the EPA has concluded that the issuance of most types of variances pursuant to S.B. 367 would be consistent with the Clean Water Act and its implementing regulations based on information provided to the

EPA at the time. The EPA's letter describes our understanding that Montana DEQ plans to propose rulemaking this spring to implement the temporary variance process and related numeric nutrient criteria.

The EPA's January 3 letter articulates the EPA's belief that former S.B. 367's issuance of "temporary" variances would generally be consistent with the CWA. Former S.B. 367 also allows the state to approve an "alternative" variance where a "permittee demonstrates that achieving nutrient concentrations established for an individual or general nutrient standards variance would result in an insignificant reduction of instream nutrient loading." The EPA is concerned with this provision because the EPA's water quality standards regulations at 40 CFR 131.10(g) do not contain a factor that would allow a variance simply because the loading is insignificant.

The EPA will be responsible for reviewing and, if appropriate, approving Montana's final proposed water quality standards revisions when they are formally submitted to EPA at the close of the rulemaking process. As reinforced in the EPA's January 3 letter, the EPA looks forward to continuing to work with Montana DEQ to support its rulemaking process and to evaluate any additional information and analysis as it becomes available.

3. **On June 24, 2011, Richard Opper, the director of the Montana Department of Environmental Quality (DEQ) and President of the Environmental Council of the States, testified before the House Transportation and Infrastructure Committee about the state of Montana's efforts to implement numeric nutrient standards that include a practical variance process. What specifically has EPA done since Mr. Opper's testimony to respond to the state of Montana's efforts?**

Since the June 24 hearing, the EPA has continued to collaborate closely with MDEQ on the State's numeric nutrient criteria rulemaking package and associated work on the statewide economic variance analyses, including the EPA's January 3, 2012 letter described above. The Agency remains engaged in productive discussions with the State and stakeholders and continues to work closely with MDEQ on options for addressing the effluent limits that would apply while the variance is in effect.

4. **Given that Montana's numeric standards, as implemented under S.B. 367, will require immediate upgrades by an estimated 70 percent of Montana's large dischargers and 30 percent of smaller dischargers, with temporary variances that must be re-justified every 3 years, how would implementation of SB. 367 fail to meet EPA's directive to find innovative solutions to nutrient loading?**

The EPA recognizes that Montana's approach reflects progress toward establishing numeric nutrient standards encouraged in the EPA's March 16, 2011 memo. With regard to the policy in Montana's law establishing nutrient standards variances (formerly Senate Bill 367) and the state's efforts to develop and adopt numeric nutrient criteria for wadeable streams, the EPA is encouraged that Montana is setting appropriate standards while at the same time making use of available flexibilities. As described in response to Question 2 above, the EPA has informed

Montana that the issuance of most types of variances pursuant to S.B. 367 would be consistent with the Clean Water Act and its implementing regulations. The EPA and MDEQ are working collaboratively to develop effluent limits that would apply while Montana's variances are in effect.

5. **Montana DEQ's economic analysis shows that the costs of deploying commercially available technology to immediately address point source discharge of total phosphorus and total nitrates would outweigh the benefits by approximately four to one. Given the often extremely high cost of currently available technology for addressing point source discharges of nutrients, what steps does EPA plan to take nationwide to encourage less costly state implementation of nutrient standards?**

The EPA recognizes that states need flexibility to develop creative and cost-effective solutions to addressing nitrogen and phosphorus pollution, and that a one-size-fits-all solution is neither desirable nor necessary. Where states develop numeric nutrient criteria, there are multiple implementation tools, including variances, permit compliance schedules, and revisions to designated uses available to states, which provide flexibility when implementing numeric nutrient criteria. For example, variances are available to states in situations where water quality standards cannot be met immediately, but where the state believes that the standard ultimately can be attained. Variances are temporary, subject to review every three years, and may be extended upon expiration. Generally, variances are an appropriate tool to consider where it can be demonstrated that it is not feasible to attain the designated use during the term of the proposed variance based on one of the factors specified in 40 CFR Section 131.10(g), such as substantial and widespread economic and social impacts. The variance requires the EPA's review and approval before it becomes effective for Clean Water Act purposes (40 CFR Section 131.21(c)). A variance temporarily establishes a less stringent water quality standard that can be met with the expectation that the discharger make feasible progress toward protecting the designated use.

On a nationwide basis, as states continue to make progress toward developing nutrient criteria and implementation programs, the EPA plans to participate actively with states and their stakeholders, describe tools and options that are consistent with the Clean Water Act, and provide careful review and technical assistance on state proposals. This work will assure that a range of practical approaches are developed to meet the needs and priorities of the various states.

One of the primary tools for achieving water quality standards on individual water bodies is a total maximum daily load (TMDL). This consists of a target level of discharges for the water body and a combination of wasteload and load allocations to point and non-point sources, respectively. Point sources receive wasteload allocations that must be reflected in their permits, while non-point sources and background sources receive load allocations. States have a great deal of flexibility in the development and implementation of TMDLs to make sensible choices that achieve water quality standards in cost-effective ways. For example, states may assign significant load reductions to non-point sources, as long as they have a mechanism under state law for providing reasonable assurance that such reductions will occur. Another approach is to establish a program for trading between point and non-point sources. Under this approach, loads reductions are assigned to the point sources, but they can purchase credits from non-point sources to meet their allocations. The EPA believes these and other innovative approaches have the potential to achieve significant nutrient reductions at reasonable cost.

Senator Benjamin Cardin

1. Please comment on the scale of the nutrient pollution problem. How many waters in the U.S. are currently impaired due to nutrients?

Nutrient pollution is a major and growing national water quality problem in both fresh and marine waters, and affects many waterbodies across the United States. On a national scale, the primary sources of nitrogen and phosphorus pollution can be grouped into five major categories:

1) urban stormwater runoff from sources associated with urban land use and development;
2) municipal and industrial wastewater discharges;
3) row crop agriculture;
4) livestock production; and
5) atmospheric deposition from the production of nitrogen oxides in electric power generation and internal combustion engines.

More than 15,000 nutrient-related impaired waters have been identified in 49 states, including 2.5 million acres of assessed lakes and reservoirs and 80,000 miles of rivers and streams. This is likely an underestimate because only a quarter of lakes and reservoirs and less than half of the nation's rivers and streams have been assessed. In terms of the estuaries and coastal waters to which many of the country's major watersheds flow, 78% of assessed continental U.S. coastal waters exhibit eutrophication, a condition caused by excess levels of nitrogen and phosphorus.

2. Which areas of the country are experiencing the greatest effects of nutrient pollution? Why?

Nutrient pollution is a major and growing national water quality problem, and it is challenging to identify specific areas experiencing the greatest effects. However, as noted above, coastal and estuarine waters are showing significant levels of nutrient-related degradation, including those in the Mid-Atlantic, Southeast, and Gulf of Mexico, as well as those in the Northwest and the Great Lakes. In addition, a recent 2010 USGS Report on Nutrients in Streams and Groundwater indicated that nitrogen concentrations are generally highest in agricultural streams in the Northeast, Midwest and Northwest.[1]

3. Human-produced nutrient pollution in U.S. freshwaters costs the U.S. economy almost $2.2 billion each year and coastal algal blooms can cost $82 million annually, according to studies reported by the Environmental Science and Technology Journal in 2009, and the Ecology Studies Series in 2006.

- **What industries are most harmed by nutrient pollution?**
- **Is there evidence that reductions in nutrient pollution create economic benefits?**
- **What are some examples?**

Nutrient pollution is a major threat to our drinking water supplies, the welfare of communities, and the health and growth of businesses and jobs that rely on a high-quality and sustainable source of water including tourism, farming, fishing, beverage production, manufacturing, and

[1] U.S. Geological Survey. 2010. USGS Circular 1350: Nutrients in the Nation's Streams and Groundwater. Available at http://water.usgs.gov/nawqa/nutrients/pubs/circ1350/.

transportation, just to name a few. The contamination of America's waters by nutrient pollution is a widespread and growing problem.

The impacts of nutrient pollution, particularly the growth of harmful algal blooms, result in significant economic losses, both at a local- and regional-scale. As described in further detail in my written testimony, examples of how nutrient pollution can affect our communities and cause negative economic impacts include:

- Decreased lakefront property values
- Loss of and decline in fisheries and recreational use (i.e., fishing, boating, swimming)
- Decreased tourism
- Increased drinking-water treatment costs
- Increased public health costs
- Increased livestock illness.

Reduction in nutrient pollution has the potential for significant economic benefits. Below are some examples of economic impacts of nutrient pollution (1) on the national scale, (2) on the regional scale and (3) as they relate to drinking water. These costs could be significantly reduced through reductions in nutrient pollution.

1. *Nationwide Estimated Economic Impacts Due to Nutrient Pollution*
   - Human-induced eutrophication in U.S. freshwaters costs approximately $2.2 billion annually, with the majority of the impacts due to losses in lakefront property values and recreational uses.[2]

   - Chesapeake Bay – The Chesapeake Bay and its rivers are unhealthy primarily because of pollution from excess nitrogen, phosphorus and sediment. Between 1998 and 2006 the decline of crabs in the Bay meant a cumulative loss to Maryland and Virginia of about $640 million (loss to restaurants, crab processors, wholesalers, grocers, and watermen).[3] Loss of Bay oysters over the last 30 years was equivalent to a loss of more than $4 billion for Maryland and Virginia.[4]

2. *Regional Estimated Economic Impacts Due to Harmful Algal Blooms*
   - Pacific Northwest- $10-$12 million in lost annual revenue to commercial, subsistence, and recreational fisheries in 2002-03 due to toxic algal blooms along the Pacific Coast. (Hoagland P, Scatasta S. 2006. The economic effects of harmful algal blooms.[5]

   - New England- $23 million in lost annual revenue to commercial fisheries in Maine and Massachusetts in 2005 due to toxic algal blooms (red tide).[6]

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[2] Dodds et al. 2009. Eutrophication of U.S. Freshwaters: Analysis of Potential Economic Damages. Environmental Science and Technology. 43:1, 12-19.
[3] Chesapeake Bay Foundation. The Economic Argument for Cleaning up the Bay and its Rivers. November 2010; Dr. James Kirkley, Virginia Institute of Marine Science. http://www.cbf.org/Document.Doc?id=591
[4] U.S. Army Corps of Engineers. 2008. Oyster Environmental Impact Statement. http://www.nao.usace.army.mil/OysterEIS/FINAL_PEIS/homepage.asp
[5] E Graneli and J Turner, eds., Ecology of Harmful Algae. Ecology Studies Series. Dordrecht, The Netherlands: Springer-Verlag, Chap. 29.

- Florida- $19-$32 million in lost annual state revenue due to recurring toxic algal blooms (red tide).[7]

- Florida – up to $5.4 billion in lost annual revenue from recreational saltwater fishing.[8]

- Maryland/Chesapeake Bay - estimated 48 million in seafood sales were lost to Maryland producers as a consequence of the 1997 *Pfisteria* event.[9]

3. *Drinking Water Economic Impacts Due to Nutrient Pollution*
   - Treating drinking water supplies to resolve taste and odor issues associated with nutrient pollution and reduce nitrate, which can cause methemoglobinemia (blue baby syndrome), is costly to communities. For example, as mentioned in my testimony, in Lancaster County, Pennsylvania, more than 140 surface and groundwater systems have had to invest in new technology such as ion exchange treatment in order to clean up nitrate contamination and protect public health.

   - In the U.S., taste and odor problems potentially associated with nutrient-polluted drinking water supplies result in an estimated $813 million (2008 dollars) per year spent on bottled water. This figure is believed to be an underestimate of the total cost of treating drinking water due to eutrophication.[10]

   - For a small community water system serving 500 or fewer people, the capital cost for ion exchange treatment to remove nitrates would be more than $280,000 with annual operating costs of $17,500. That capital cost increases to over $550,000 with annual operating costs of over $50,000 for a community water system serving 3,300 people.[11]

   - Often, problems occur in rural areas and for small systems with limited resources. In 2009 and 2010, based on EPA data, 69% of nitrate violations in community water systems occurred at systems serving fewer than 500 people.

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[6] NOAA Center for Sponsored Coastal Ocean Research. 2008. Economic Impacts of Harmful Algal Blooms. http://www.cop.noaa.gov/stressors/extremeevents/hab/current/econimpact_08.pdf

[7] NOAA Center for Sponsored Coastal Ocean Research. 2008. Economic Impacts of Harmful Algal Blooms. http://www.cop.noaa.gov/stressors/extremeevents/hab/current/econimpact_08.pdf.

[8] Florida Fish and Wildlife Commission (FWC). 2010. The Economic Impact of Saltwater Fishing in Florida. http://myfwc.com/conservation/value/saltwater-fishing/). Saltwater anglers averaged 10.8 million fishing trips per year within Florida's territorial sea from 2005 to 2009 (NOAA. 2011. NOAA Fisheries: Recreational Fisheries Statistics Queries. http://www.st.nmfs.noaa.gov/st1/recreational/queries/index.html.

[9] Lipton 1999. Estimated Annual Economic Impacts from Harmful Algal Blooms in the United States by Donald Anderson, Porter Hoagland, Yoshi Kaoru, Alan W. White 1990.

[10] Dodds et al. 2009. Eutrophication of U.S. Freshwaters: Analysis of Potential Economic Damages. Environmental Science and Technology. 43:1, 12-19.

[11] NITG. 2009. An Urgent Call to Action: Report of the State-EPA Nutrient Innovations Task Group.

- In Fremont, Ohio (population= 20,000), numerous drinking water violations due to high nitrate concentrations have lead to the need for an estimated $15 million to build a reservoir as an alternate water supply.[12]

- In regulating allowable levels of chlorophyll-a in Oklahoma drinking water reservoirs, a problem due to nutrient pollution, the Oklahoma Water Resources Board estimated that the long-term cost savings in drinking water treatment for 86 systems would range from $106 to $615 million if such regulations were implemented.[13]

4. The Clean Water Act requires that local jurisdictions develop TMDLs for waters too polluted to meet local quality standards. The Chesapeake Bay currently has the largest TMDL. What is a TMDL and how effective have TMDLs been in improving water quality?

A total maximum daily load (TMDL) is a calculation of the maximum amount of a pollutant that can enter a water body and still meet all applicable water quality standards - both narrative and numeric. This maximum pollutant "diet" is allocated to the point sources (e.g., publicly owned treatment works, industrial, and some stormwater sources) and non-point sources (e.g., agricultural runoff, atmospheric deposition). The TMDL must reflect critical conditions and seasonality, and must also contain a margin of safety to account for uncertainties between the loadings and the water quality response. The allocations assigned to point sources (wasteload allocations) are reflected in NPDES permits issued by the states (or the EPA). Waters requiring the calculation of a TMDL are those identified as impaired by the states and submitted to the EPA on a biennial frequency. After this list of impaired waters is approved by the EPA, it is the EPA's policy that a TMDL should be developed and submitted to the EPA within 8-13 years.

The EPA is leading the development of the 2010 Chesapeake Bay Total Maximum Daily Load (TMDL. The EPA's TMDL establishes the maximum amount of pollution the Chesapeake Bay estuary can receive and still meet water quality standards. In turn, the seven Chesapeake Bay jurisdictions, which include six states and the District of Columbia, determine the sector allocations and strategies for reducing nutrients in order to meet overall state-level reduction goals established by the TMDL.

TMDLs have contributed and continue to contribute to restoring and maintaining the quality of the nation's waters in several important ways. TMDLs provide an initial quantitative plan to reduce pollution, organize restoration efforts, identify potentially involved parties, and help focus pollution budgeting on what is most useful for reestablishing the beneficial uses of a healthy water body. They also provide a public involvement process to engage stakeholders. Some 50,000 TMDLs have been approved.

TMDLs, once implemented, enable steps to be taken that facilitate water quality improvement, although all TMDLs have not been fully implemented nationwide. A 2009 six-state analysis showed that 80% of TMDLs were at least partially implemented (89% of point source/mixed

[12] NITG. 2009. An Urgent Call to Action: Report of the State-EPA Nutrient Innovations Task Group.
[13] US EPA. Section 319 Nonpoint Source Success Stories. http://water.epa.gov/polwaste/nps/success319/.

TMDLs, 73% of nonpoint source TMDLs). In a 2010 national study, 95% of NPDES permits with specific TMDL wasteload allocations were meeting the terms of their TMDLs.

Although nonpoint source controls are voluntary and remain the biggest challenge facing US water quality improvement, a 2010 study relating CWA Section 319 nonpoint control projects to TMDLs identified 2,746 Section 319 projects reporting involvement with developing or implementing a TMDL. Most impaired waters take years to decades to recover fully, but evidence is growing that TMDLs are helping to successfully catalyze water quality improvement. For example, a 2008 EPA-funded analysis of TMDLs in two states (Ohio and West Virginia) observed that pollutant loading reductions had already occurred subsequent to 46% of the TMDLs assessed, and ongoing water quality improvements were detected in 19% of the waters addressed by the TMDLs, despite the short time frame that elapsed since their completion.[14]

5. How do the EPA and USDA coordinate their current efforts in fighting nutrient pollution? Should this partnership, based on its results, continue?

The EPA and USDA have been collaborating for well over a decade at the national, regional and state levels, and will continue to collaborate. In fact, we support even more enhanced collaboration in the years ahead. Both agencies value the critical work that American farmers are doing to protect our soil, air, and water resources. We believe that environmentally sound farming is essential to a thriving agricultural community and a sustainable environment. Agriculture is a key part of the American economy and way of life, and has an important role in watershed restoration efforts. EPA and USDA are both committed to working together and with their partners to help ensure that farmers can continue producing food and fiber while reducing nutrient pollution and improving water quality.

The EPA and the U.S. Department of Agriculture (USDA) collaborate closely, leveraging each agency's expertise through implementation of their respective programs. EPA provides its latest science to help advise USDA on key priorities for advancing water quality-based conservation practices and innovative solutions to agricultural challenges affecting water quality.

EPA and USDA also coordinate federal funding programs to ensure the most efficient use of federal funds to deal with agricultural challenges facing water quality. Typically, these programs include the EPA's implementation of the national program to control nonpoint sources of pollution under Section 319 of the Clean Water Act and USDA's implementation of the Farm Bill Conservation Programs. These programs are complementary and enable the strengths and resources of each agency, including the agencies' state partners, to be employed in a manner that maximizes overall effectiveness of the programs.

The EPA/USDA collaboration has been further strengthened in the past several years, and the agencies continue to work together and with the states to create effective partnership opportunities. On a regional level, the agencies have been working together in the Chesapeake Bay region to advance concepts like Agricultural Certainty that will provide positive incentives

[14] Implementing Total Maximum Daily Loads: Understanding and Fostering Successful Results. Available at http://www.epa.gov/owow/tmdl/results/pdf/12kentst_tmdl_rpt.pdf.

to the agricultural community to further address water resource issues. The goal of our collaboration is to increase conservation on the ground and to better protect water resources from nonpoint sources of pollution, including nitrogen and phosphorus. The EPA and USDA collaborate with states, other federal agencies, and stakeholders to enhance resources and resource conservation in order to improve water quality and habitat, reduce nutrient loading, and, through water quality monitoring and assessments, track changes and improvements that take place across the landscape as the result of watershed planning and voluntary adoption of conservation systems by agricultural producers. Coordination needs and opportunities vary in particular watersheds, but the agencies often pursue a common template in coordination with state partners, such as:

- The EPA's 319-funded state partners or their subgrantees (such as conservation districts) develop watershed plans;
- USDA contracts with landowners who implement Best Management Practices;
- USDA and/or the State 319 agency provides technical assistance to landowners; and
- The state monitors water quality to support adaptive management and document water quality improvements.

The EPA, USDA, and state section 319 agencies have made increasingly concerted efforts to coordinate as USDA implements geographically targeted initiatives in the Chesapeake Bay, Mississippi River Basin, Gulf of Mexico and elsewhere.

The EPA and USDA also coordinate via the Mississippi River/Gulf of Mexico Watershed Nutrient (Hypoxia) Task Force and the Great Lakes Restoration Initiative to support state efforts to develop and implement comprehensive nutrient management strategies for agricultural nonpoint source pollution.

The EPA believes the USDA-EPA partnership should continue and be strengthened.

6. Do you think a nutrient-trading program would be an effective way to manage and reduce nutrient pollution? Why or why not?

Yes. The EPA supports nutrient trading and offsets as a tool to protect water quality standards and meet water quality-based effluent limitations. EPA and other Federal agencies believe nutrient credit trading can be an important part of reducing nutrient pollution and achieving water quality goals in a cost-effective way. In 2003, the EPA issued a policy on nutrient trading, followed up by a toolkit in 2007. Nutrient trading has proven to be an effective way to manage and reduce nutrient pollution in such states as Connecticut, Virginia, and North Carolina.

The EPA also included trading and offsets as a tool to manage nutrient pollution in the Chesapeake Bay TMDL, issued in 2010. EPA and our Federal partners would support efforts to implement inter-jurisdictional, intra-basin trading of nutrient credits that is conducted consistent with the Clean Water Act and the trading-related definitions, elements and safeguards in Appendix S of EPA's Chesapeake Bay Total Maximum Daily Load (TMDL).

Senator James Inhofe

1. **Your March 16, 2011, nutrient management "framework" memo states that EPA will be flexible and encourage state innovation in dealing with nutrient pollution. You indicate that a one-size-fits-all solution is neither desirable nor necessary. Yet states feel EPA has been inflexible in pushing only for the adoption of numerical nutrient criteria and has been resistant to the measured approaches proposed by several state and interstate agencies. Please describe where your flexibility exists in this approach.**

The EPA recognizes the lead role provided to states by the Clean Water Act for adopting and implementing water quality standards. Decisions about water quality standards are primarily made by states, subject to review by the EPA to ensure that the standards comply with the Clean Water Act and its implementing regulations. The March 16th Framework Memo provides the EPA's recommendations for an effective framework to address nutrient pollution. We believe that the recommendations provide a helpful framework that may be tailored to particular state circumstances, taking into account existing tools and innovative approaches, available resources, and the need to engage all sectors and parties in developing strategies to address nutrient pollution. In the Memo, the EPA encourages states to work with stakeholders to develop a state nutrient reduction strategy, recognizing the importance of ongoing activities and the innovative ideas that are working to reduce nutrients. The Framework Memo recommends state adoption of numeric nutrient criteria on a reasonable timeframe, which the EPA believes will better enable states to effectively protect local and downstream waters from nitrogen and phosphorus pollution. However, the Framework Memo is guidance only, and states may adopt alternate approaches for addressing nutrient pollution as long as they are consistent with the requirements of the Clean Water Act. The EPA stands ready to work with States to tailor a nutrient reduction approach to particular state circumstances.

The EPA recognizes that states need flexibility to develop creative and cost-effective solutions to addressing nitrogen and phosphorus pollution, and that a one-size-fits-all solution is neither desirable nor necessary. There is a large range of implementation tools for nutrient criteria that are available to states, including variances, site specific alternative criteria, compliance schedule provisions, nutrient trading, and revised designated uses provisions, which provide flexibility to implement nutrient criteria in an effective and cost-effective manner.

2. **During the hearing, the second panel discussed using a combination of standards to evaluate the health of waterbodies. For example, numeric criteria and narrative standards are used together to assess nutrient levels in waterbodies based on a cause and effect relationship.**
    a. **Do you agree that this can be an effective way to measure the health of waterbodies and, specifically, using numeric nutrient criteria in concert with narrative standards?**
    b. **What is your scientific basis for insisting on independently applicable numeric standards?**

The EPA has not insisted upon or mandated that States adopt independently applicable numeric nutrient criteria. The EPA has recommended that states adopt numeric criteria because we believe this provides an effective basis for implementing programs to protect water quality form nutrient discharges. As discussed above, the EPA believes that there is ample flexibility in the Clean Water Act to support a variety of effective and cost-effective implementation approaches for both numeric and non-numeric criteria. However, we believe numeric criteria can facilitate more effective program implementation, provide greater efficiency than site-specific application of narrative criteria, and provide a clearer target for water quality improvement. The EPA continues to recognize that states have primary responsibility for the development and implementation of their water quality standards, and stands ready to work with States to tailor a nutrient reduction approach to particular state circumstances.

The EPA believes that a variety of approaches should be used when evaluating water quality data and determining the ultimate health of a waterbody in order to most effectively restore and maintain the chemical, physical, and biological integrity of the nation's waters. With respect to narrative criteria, the EPA agrees that narrative nutrient criteria can effectively be used in combination with quantitative biocriteria to assess existing water quality in a way that accounts for both near-field, as well as far-field downstream impacts. In this regard, the Office of Water has just completed an extensive overview of biological assessment methodologies including 16 case studies of impressive state work in this area. As the primer indicates, "[i]t is EPA's long standing policy that biological assessments should be fully integrated in state and Tribal water quality programs."

With regard to the EPA's independent applicability policy, it is based on the premise that any valid, representative dataset indicating an actual or projected water quality impairment should not be ignored when one is determining the appropriate action to be taken. The policy was developed more than 20 years ago and has been peer reviewed. The EPA recognizes that there are circumstances when conflicting results should be investigated further before an attainment or nonattainment decision is made. The intent of this policy is to protect against dismissing valuable information when evaluating aquatic life use attainment, particularly in detecting impairment.

Particularly with respect to nutrients, it is important to emphasize that this policy does not preclude states from adopting a scientifically defensible approach for developing nutrient criteria that recognizes the interrelationship between nitrogen and phosphorous in causing waterbody impairment. The EPA recommends the integration of numeric nutrient criteria with quantitative biometric criteria and will continue to work with states on the use of a multiple lines of evidence approach in applying nutrient criteria that is preventive, protective of downstream water quality standards, and scientifically defensible.

3. **Recently, the Scientific and Technical Advisory Committee (STAC) to the Chesapeake Bay Program came out with a report that criticized the Limno-Tech comparison between the assumptions in EPA's TMDL about agriculture and the NRCS CEAP report on agricultural impacts on the Chesapeake Bay. The Committee's primary disagreement with Limno-Tech was the conclusion that the TMDL should be delayed until data issues were resolved. After recalculating EPA's numbers to use 2005 data, the Committee determined that the differences between the CEAP estimates and EPA's estimates of nitrogen and sediment coming from agriculture were 15% and 29%,**

respectively. STAC has told EPA that they need to address, or at least admit, the uncertainties in the TMDL models in this report, the 2008 peer review and in the STAC review of the new land use data from last November.

a. **How will EPA respond to this concern about the uncertainties in the TMDL?**
b. **Will EPA address the differences between the CEAP data and EPA data? If so, how?**
c. **Since EPA isn't planning to amend the TMDL until 2017, the allocations in the TMDL are frozen, you are asking states to make an investment of over $40 billion. Is a 29% margin of error that you might be making the investment in the wrong places acceptable?**
d. **How does EPA plan to compensate for investments that are made in the wrong places as a result of the 15-29% uncertainty?**

STAC's review committee criticized the report prepared by LimnoTech for the Agricultural Nutrient Policy Council for having poor scientific merit, promoting false criteria for models, using selective interpretation of the CEAP report, and having errors in the interpretation of the models and results. In response to an October 8 letter to the editor of the Washington Post by the President of the American Farm Bureau, STAC posted a response on its web site stating that it would not be legitimate to interpret the percentage differences between the CEAP and Chesapeake Bay Program Partnership's models as a margin of error for either model.

The STAC borrowed heavily from a 2007 National Research Council report entitled *Models in Environmental Regulatory Decision Making* in asserting that models, by their nature, are uncertain but necessary for effective decision making. STAC stated that "measures of uncertainty are intrinsically reflected in the margin of safety for the TMDL, and thus imprecision is acknowledged to be present both in the models and in the statement of the TMDL", and further that "[a]daptive management (not delay or inaction) is the proper response to uncertainty in knowledge, including differences between models".

Despite being built for two different purposes, the CBP Watershed Model and the CEAP model are in agreement in terms of relative nutrient loads from agricultural lands at the large basin scale and the additional management actions that are needed. Although the CEAP model was not built to be a TMDL model, it provides some valuable information that will help enrich the CBP Watershed Model.

The EPA and USDA have been collaborating on the CEAP report since its inception and conducted preliminary model results comparisons in the summer of 2010, before the CEAP report or the LimnoTech report were complete. On June 28, 2011, USDA and EPA developed the *USDA and EPA Chesapeake Data Collaboration Workplan* that maps out a plan for our continued collaboration. Implementation of this workplan will further refine our accounting of agricultural conservation practices throughout the Bay watershed, bolster the scientific defensibility of the benefits of agricultural conservation practices, and improve consistency of data used in our agencies' respective decision support tools. In their review, STAC commended the EPA and USDA for this collaborative workplan.

The Bay jurisdictions are creating plans to implement controls by 2017 that are intended to reach 60% of the TMDL goal. At that point a re-evaluation will be performed to make appropriate mid-course corrections. It is unlikely that a jurisdiction will over-control for nutrients and sediment during the interceding period.

4. **Last October, EPA issued a contract to Tetra Tech to help with nutrient issues. Task 7 of Tetra Tech Task Order is called "Scientific Study and Modeling for Mississippi River and Gulf of Mexico Nutrient Criteria Development." Under this task, Tetra Tech is to develop a model by November of this year and establish numeric nutrient concentrations by April 2012. This committee has expressed concerns that this is an extremely large task, undertaken in an incredibly short amount of time and likely to result in high amounts of uncertainty.**
   a. **What is the status of this work?**
   b. **Will it be used to develop a TMDL for the Northern Gulf of Mexico?**
   c. **Will it be used to develop a TMDL for the Mississippi River Basin?**
   d. **What will EPA do to ensure that numeric concentrations in the Tetra Tech model do not face the same criticisms that the Chesapeake Bay TMDL has come under?**

The EPA is currently in the process of having a work plan developed for this task, and the aforementioned dates were best-case-scenario deadlines. After the work plan has been developed, the EPA intends to submit the plan to an independent scientific peer review.

The task is intended to assist states that wish to use it in the development of numeric nutrient criteria. It is not intended to be used to develop a TMDL for the northern Gulf of Mexico or the Mississippi River Basin.

5. **EPA has added 3 segments of the Northern Gulf of Mexico to the State of Louisiana's list of impaired waters because they have low dissolved oxygen, likely as a result of nutrients.**
   a. **Will EPA develop a TMDL for these waters if the state does not?**
   b. **Since the State of Louisiana does not have the authority to control pollution from outside the state's boundaries, does EPA's action mean that EPA is taking the first steps to a multi-state federal TMDL, affecting the entire Mississippi River Basin?**

The EPA has no plans to establish a TMDL for the three Louisiana coastal segments that the EPA added to Louisiana's 2008 Clean Water Act Section 303(d) list and has proposed to add to Louisiana's 2010 Section 303(d) list. Once waters are added to Louisiana's Clean Water Act Section 303(d) list of impaired waters, development of a Total Maximum Daily Load (TMDL) is required pursuant to Section 303(d)(1)(C) of the Clean Water Act. Consistent with the complementary Federal-State roles outlined in the Clean Water Act, the State of Louisiana will take the lead in developing TMDLs for these segments. The EPA stands ready to assist Louisiana in its TMDL development, and has the obligation to review and approve (or disapprove) each TMDL when developed by the State and submitted to the EPA.

The EPA's action to add these segments to Louisiana's Clean Water Act Section 303(d) list of impaired waters also does not mean that the EPA is taking the first steps to a multi-state federal TMDL. We recognize the need to work collaboratively with states, other partners and stakeholders to account for all sources of nutrients that potentially cause or contribute to waterbody impairment and make stronger, near-term, and local progress on reducing nitrogen and phosphorus pollution in the Mississippi River Basin while states continue to develop their numeric nutrient criteria. Actions such as numeric or narrative criteria development may accelerate TMDL development for nutrients in all states potentially linked to the Mississippi River basin, whereas it may take many years of scientific and programmatic work to develop a TMDL for such a large area of the country. Under the Clean Water Act, states have a responsibility to protect the quality of downstream waters, and this must be accounted for in the development of state TMDLs.

6. **On April 22, 2011, the Florida Department of Environmental Protection (DEP) filed a petition with EPA asking the federal agency to withdraw its January 14, 2009, determination that numeric nutrient criteria are necessary in Florida, to repeal EPA's existing rule, and "discontinue proposing or promulgating further numeric nutrient criteria in Florida." DEP requested EPA to respond within 30 days of the date of the petition, but EPA has only given an "initial response." By what date will you give Florida a yes or no answer?**

The EPA expects to hold the petition in abeyance pending the results of Florida DEP's rulemaking process. The EPA has been encouraged by the progress that Florida has made thus far. The EPA noted in a November 2, 2011 letter to Florida that its preliminary evaluation of the State's October 24, 2011 version of the draft rule leads the EPA to the preliminary conclusion that EPA would be able to approve, if finalized, the October 24, 2011 version of the draft rule under the Clean Water Act. Should EPA formally approve FDEP's final nutrient criteria as consistent with the CWA, the EPA would initiate rulemaking to withdraw Federal numeric nutrient criteria for any waters covered by the new and approved state water quality standards.[15]

7. **At the hearing, you noted the widespread disparities in cost estimates of implementation for Florida's numeric nutrient criteria were due in part to how variances were estimated.**
   a. **Why has EPA calculated a compliance cost projection that assumes widespread variances and exceptions from your Florida nutrient criteria rule?**

[15] On February 18, 2012, Judge Robert L. Hinkle of the U.S. District Court for the Northern District of Florida (Tallahassee Division) issued an Order on the Merits in *Florida Wildlife Federation, et al. v. Johnson*, Consolidated Case No. 4:08cv324-RH/WCS. The Court upheld the EPA's 2009 determination that new or revised standards for nutrients in the form of numeric nutrient criteria were necessary in Florida, and upheld the EPA's rule setting numeric nutrient criteria for Florida in all respects except for the stream criteria and default downstream protection criteria for unimpaired lakes. The Court modified the existing consent decree to require the Administrator to sign for publication proposed rules setting numeric nutrient criteria for streams and default downstream protection values for unimpaired lakes by May 21, 2012, or to sign for publication final rules setting numeric nutrient criteria for streams and default downstream protection values for unimpaired lakes by May 21, 2012. Note that for downstream protection values for unimpaired lakes, the EPA is not subject to either May 21, 2012 deadline if by that date the EPA has filed a notice that it has decided not to propose or adopt such criteria, together with an explanation of the decision.

b. If EPA believes that these numeric standards are necessary for the health of Florida waters, then how, for the purpose of determining the economic impact, can EPA assume that regulated entities in Florida will not have to comply with the standards?

The EPA analyzed the costs that could result from implementing the federal numeric nutrient criteria for lakes and flowing waters in the state based on how Florida currently implements its water quality standards program. To avoid expensive technology requirements, the EPA believes Florida would likely implement cost-effective strategies that may include reuse, site-specific alternative criteria, variances, and designated use modifications.

There are no requirements in EPA-issued criteria for how reductions of nutrients would be made for any specific source of nutrients. States have flexibility to determine how best to achieve water quality standards in the most cost-effective manner. They may modify designated uses, issue variances, allow compliance schedules, and/or determine waste load allocations and load allocations when developing total maximum daily loads.

Several tools are available to states that offer flexibility: variances, permit compliance schedules, revisions to designated uses based on a use attainability analysis, and adoption of site-specific criteria. Variances are available to states in situations where water quality standards cannot be met immediately, but where the state believes that the standard ultimately can be attained. Variances are temporary, subject to review every three years, and may be extended upon expiration. Generally, variances are an appropriate tool to consider where it can be demonstrated that it is not feasible to attain the designated use during the term of the proposed variance based on one or more of the factors specified in 40 CFR Section 131.10(g), such as substantial and widespread economic and social impacts. The variance requires the EPA's review and approval before it becomes effective for Clean Water Act purposes (40 CFR Section 131.21(c)). A variance temporarily establishes a less stringent water quality standard that can be met with the expectation that the discharger make feasible progress toward protecting the designated use. The EPA's inclusion of variances in its costing assumptions for the Florida Phase 1 nutrient standards reflect its judgment that use of such variances would generally meet the requirements of the Clean Water Act and be supportable in the context of implementation of the standards.

The EPA recognizes that states need flexibility to develop creative and cost-effective solutions to addressing nitrogen and phosphorus pollution, and that a one-size-fits-all solution is neither desirable nor necessary. If states develop numeric nutrient criteria, there are a large range of implementation tools, including variances and designated uses, available to states, which provide adequate flexibility to implement numeric nutrient criteria.

In January 2009 the EPA determined that numeric standards are necessary to protect state designated uses for the State of Florida's waters. As noted above, the EPA is not implementing numeric nutrient criteria for Florida. After the numeric nutrient water quality standards become effective, implementation will be phased in as water quality assessments are completed and impaired waters are identified; total maximum daily loads are calculated and implemented; and NPDES permits are renewed. In each of these processes, there are opportunities for public participation and further scientific and technical analysis. As an authorized state, the FDEP has the primary responsibility of setting priorities and carrying out these actions with oversight and assistance from the EPA.

A recent draft economic analysis by Florida State University on behalf of the FDEP suggests that implementing numeric nutrient criteria for both Florida inland waters and some estuarine regions on the same criteria values that were reflected in EPA's inland water rule will cost, on balance, less than earlier estimates provided by FDEP.[16] On the subject of projected costs, the EPA has requested that the National Academy of Sciences assemble a committee of recognized experts to review the Agency's economic analyses as well as consider the basis for alternative estimates. That review is underway.

For its economic analysis of the Florida Phase 2 Nutrient Standards Rule, the EPA is carefully considering the feedback it has received on the economic analysis for the Phase 1 rule. The EPA will address the issues raised in these public comments in preparing its draft analysis for the Phase 2 rule and request public comment.

8. **In April 2010, EPA's Science Advisory Board (SAB) reviewed EPA's nutrient criteria development guidance memo and criticized EPA's statistical nutrient criteria development methods because the methods were not based on cause and effect relationships between nutrients and biological harm. In January 2010, EPA admitted that its proposed rivers and streams standards for Florida were based on statistical assumptions, not cause and effect relationships.**
    a. **Why did EPA use scientific methods for its Florida nutrient criteria rule that have been criticized by the SAB?**
    b. **Couldn't many of the concerns regarding EPA's scientific methods be put to rest if EPA subjected these specific criteria to an independent scientific peer review between now and March 2012 when the criteria are set to be finalized?**
    c. **Will you commit to a scientific review, yes or no?**
    d. **Will you be updating your framework memo to address the SABs concerns? Why or why not?**

The Science Advisory Board (SAB) reviewed the EPA's draft technical support document for states to use when deriving numeric nutrient criteria using stressor-response relationships, *Empirical Approaches for Numeric Nutrient Criteria Development.* Stressor-response relationships are one of three general approaches that the EPA recommends for states to use when deriving numeric nutrient criteria. The EPA had previously published peer-reviewed general guidance documents that outline these three approaches. The SAB reviewed a supplemental technical support document that provided more detail on use of stressor-response relationships. The SAB determined that the "stressor-response approach is a legitimate, scientifically based method for developing numeric nutrient criteria if the approach is appropriately applied." The SAB's criticisms were not directed to the approach itself, but rather to the detail provided in the technical support document to assist states in the use of this approach. The EPA revised this document to address the SAB's concerns; namely, to present a more "complete and balanced view of using statistical methods to develop the criteria . . . to make the document more useful to state and tribal water quality scientists and resource

[16] http://static-lobbytools.s3.amazonaws.com/press/20111206_20111206_final_draft_nnc_cost_analysis.pdf

managers." This revised technical support document, *Using Stressor-response Relationships to Derive Numeric Nutrient Criteria* (EPA-820-S-10-001), was released in final form in November 2010. When establishing numeric nutrient criteria for Florida's lakes, the EPA utilized the stressor-response approach in an appropriate application in an approach that is consistent with the SAB's comments.

The EPA subjected the numeric nutrient criteria technical analysis to an independent scientific peer review prior to the rule being finalized in December 2010. The result of the peer review that was conducted in the summer of 2009 (final report was submitted on September 8, 2009) and the EPA's response to the peer review comments is part of the administrative record for that rule.

The March 16, 2011, framework memo does not specify how to derive numeric nutrient criteria. It merely recommends that states establish a work plan and phased schedule for developing nitrogen and phosphorus criteria for classes of waters (e.g., lakes and reservoirs, or rivers and streams).

9. **Some areas of the country have extensively modified streams and rivers, which were channelized into concrete-lined flood control channels.**
    a. **Should nutrients in concrete-line flood control channels be regulated the same way as natural streams?**
    b. **How should nutrient criteria for these altered habitats (warmer water temperature, no reproducing population of fish and poor general habitat) be different than the criteria for more natural streams?**

The Clean Water Act provides states with flexibility in terms of setting water quality standards for their waterbodies, whether those waterbodies are extensively modified or pristine. Water quality criteria, such as numeric nutrient criteria, are only one part of water quality standards. The other two parts are designated uses and antidegradation requirements . As defined by the Clean Water Act and the implementing regulations, water quality standards "shall consist of the designated uses of the navigable waters involved and the water quality criteria for such waters based upon such uses." CWA Section 303(c)(2)(A). In turn, water quality criteria "protect the designated use. Such criteria must be based on sound scientific rationale and must contain sufficient parameters or constituents to protect the designated use" (40 CFR 131.11).

Based on the characteristic of each waterbody, states set designated uses for that waterbody, consistent with the Clean Water Act and implementing regulations. States must then ensure that water quality criteria are set to protect this designated use.

Senator David Vitter

1. Has the EPA done any sort of an estimate to determine how much it will cost producers to comply with the Sec. 308 request that was sent to OMB in early August?

The EPA described burden and costs of the proposed rule in the Impact Analysis chapter of the preamble to its October 21, 2011 proposed rule. The proposed rule would not alter existing NPDES technical requirements for CAFOs, and therefore the cost impacts to CAFOs from the rulemaking are limited to the information collection burden it would impose. The EPA estimated this burden as part of the assessment of the administrative burden impacts that the Agency is required to complete under the Paperwork Reduction Act (PRA). The EPA submitted this analysis for review by the Office of Management and Budget (OMB) as stipulated in the PRA. We have enclosed a copy of this analysis along with our response to your letter.

As a starting point for estimating the reporting burden faced by CAFOs under the proposed rule, the EPA examined its PRA analyses as approved by OMB for the 2003 and 2008 CAFO rules. For these analyses, the EPA had already accounted for the time CAFOs would require to document any nutrient management practices pursuant to these rules. These analyses had also estimated that those CAFOs applying for NPDES permit coverage under these rules would incur a nine-hour administrative burden to complete and file NPDES permit applications or notices of intent to be covered by a general NPDES permit. This nine-hour estimate includes the effort to report and calculate a variety of detailed information relevant to the CAFO, including estimates of quantities of different waste types generated and transferred, type and capacity of waste storage and containment structures, and manure uses and land application best management practices at the facility.

In light of this prior estimate of nine hours to complete a full NPDES CAFO permit application, the EPA estimated that CAFOs would incur an hour of labor to answer the more basic questions under discussion for the reporting rule. Permitted facilities would have the information on hand as part of the permit application itself. Unpermitted facilities were also assumed to have the requested information readily on hand as a result of having assessed whether or not they need to apply for a permit and then ensuring that their facility continues to operate as a CAFO that does not discharge, including whether the operation has adequate land available if the operation land applies manure, litter, and process wastewater. Therefore, all CAFOs should have the five items proposed in the reporting rule readily available.

The EPA then combined the estimates of numbers of CAFOs that would be required to respond to the information collection request in the proposed rule with the estimates of the reporting burden under the proposed rule. EPA thus projected that CAFO operators would collectively experience an increase in total annual administrative burden of approximately $200,000 on a national basis, or $29.30 per facility.

In addition, as part of the required analysis under the Regulatory Flexibility Act, the EPA compared the administrative costs that would be incurred by CAFOs under the proposed rule to the existing compliance burden of NPDES CAFO regulations. The Agency concluded that the increment in annualized compliance costs would be significantly less than one percent of estimated annual sales for any of the affected entities.

2. Do you believe that EPA has overstepped its authority under the CWA in sending the 308 request to all CAFOs, instead of just those that have discharged? It seems to me, based on the 5th Circuit's recent ruling that your authority over livestock operations ends with point sources, which the court determined were only those operations that have actually discharged. ***Is requiring information from more than that category of operations beyond EPA's [authority]?***

The EPA has interpreted the definition of "point source" as encompassing all CAFOs since the 1970s.

The Fifth Circuit Court decision in *National Pork Producers Council v. EPA (NPPC v. EPA)* does not address CWA § 308 Information Collection Authority. *NPPC v. EPA* vacated EPA's 2008 regulation requiring CAFOs that "propose to discharge" obtain NPDES permits. The vacated permit requirement for CAFOs that propose to discharge was based on CWA §§ 301 and 402 (which prohibit *actual* discharges without a permit), as well as § 308. EPA's broad information collection authority under § 308 was neither challenged nor addressed in the decision.

The EPA proposes to gather information from CAFOs pursuant to its authority in CWA section 308 to collect information. Section 308 authorizes information collection from "point sources," which includes CAFOs that discharge or may discharge. 33 U.S.C 1318(a); 1362(14) (the term "point source" is defined as "any discernible, confined, and discrete conveyance, including... any . . . concentrated animal feeding operation . . . from which pollutants are or may be discharged . . ."). The plain language of section 308 authorizes information collection to carry out the objectives of the Act, specifically including assisting in developing, implementing, and enforcing effluent limitations or standards, such as the prohibition against discharging without a permit. 33 U.S.C. 1318(a).

Site-specific information is critical for enabling the EPA and authorized States to provide well-informed NPDES program direction (including issuance of regulations, policy and guidance documents), to provide oversight and enforcement of the NPDES program for CAFOs, to inform Congress and the public about environmental and human health impacts of CAFOs, and to better ensure protection of human health and the environment. The information the EPA proposes to collect is limited to basic information about CAFOs, and the EPA proposed two options for defining the universe of facilities from which this information would be collected. The first proposed option would enable the EPA, states, and others to determine the number of CAFOs in the United States and where they are located. The second proposed option would gather this information only for CAFOs in focus watersheds where there are greater water quality concerns associated with CAFOs. Under either option, this information would assist the EPA in developing, implementing, and enforcing the requirements of the Act.

3. There are many food security issues relating to this request, which will put all CAFO operations locations on the internet. ***Has Homeland Security at any juncture raised issues with this? Isn't the agriculture industry considered one of the seven "critical infrastructures" for Homeland Security? From a national security standpoint would you think that posting on***

a national website the location of all of these operations that produce a large portion of our food put that "critical infrastructure" at risk? Does EPA ever do any analysis on food security issues prior to taking an action?

Section 308 of the Clean Water Act requires all information that the EPA collects to be available to the public, except information that it determines, according to its existing confidentiality regulations, is confidential business information. There is an extensive amount of CAFO facility-specific location information already available on the Internet from certain State permitting programs that provide the facility's name, city, animal numbers, and maps with location data on individual CAFOs. However, as noted above, the EPA believes that additional site-specific information is critical for enabling the EPA and authorized States to effectively administer their NPDES programs. In its proposed CAFO reporting rule, EPA seeks comment on what data might be considered confidential.

To address potential privacy and security-related concerns, the EPA changed the proposed survey form during inter-agency review to allow CAFO owners or operators the option of providing either their contact information or that of an authorized representative. In addition, the EPA also proposed allowing CAFO owners or operators the choice of providing the street address of the CAFO production area as an alternative to its latitude and longitude. Finally, the EPA sought comment on additional alternatives to submission of the latitude and longitude that would provide general information on a facility's location but not specific coordinates. For example, the EPA requested comment on the possibility of requesting the name of the nearest waterbody to the CAFO, based on local knowledge or US Geological Survey topographical maps. The EPA also requested comment on using other systems, such as the Public Land Survey System (PLSS) (i.e. township, range and county information) to identify the location of a CAFO's production area; or requesting a business address in lieu of the production area location.

In the EPA's proposed information collection rule, the Agency has specifically requested comment on privacy or biosecurity concerns, on appropriate ways to address those concerns, and on appropriate formats or venues through which to make collected information available to the public. Making information available to the public does not necessarily mean that all information is made available via the internet, and the EPA's proposed rule does not suggest that we plan to do so. The EPA also requested comment on whether the requirement to make any information collected pursuant to section 308 available to the public (except confidential business information) should factor into its determination about what information, if any, to collect from CAFOs. The EPA plans a robust review of all comments submitted during the public notice and comment period, including concerns related to homeland security, and will evaluate all concerns raised in developing its final action.

Senator CARDIN. Thank you very much for your testimony.
Mr. White.

STATEMENT OF DAVE WHITE, CHIEF, NATURAL RESOURCES CONSERVATION SERVICE, U.S. DEPARTMENT OF AGRICULTURE

Mr. WHITE. Greetings. It is a great honor to be here, and I thank you all very much for having me.

My colleagues have given an overview of the issue and the science. I would like you to think of the United States, picture the map, just the coterminous United States, the lower 48. Seventy percent of that land is owned by private individuals. And we believe, or I believe, that you can do anything you want with the Federal land, State land, county land, city land, the health of our environment, the fate of our environment rests in the hands of our private landowners, the men and women who own and operate that land.

And that's who NRCS primarily works with. We have a lot of programs, you guys are very gracious in the funding that you have provided through the Farm Bill. And I will visit with you some on how we are implementing those.

But just this last Fiscal Year we concluded last Friday, we were able, if you look at our five biggest cost share programs, to enter into 55,000 contracts with farmers and ranchers across this Country, many of them focused exclusively on water quality. At the same time, we had 26,000 unfunded applications. So we have like a 50 percent backlog.+

So if anyone ever questions the desire, the commitment of our farmers and ranchers to do what is right for the environment, to care about wildlife and the air and the water we drink, just let them talk to me. Because I feel their commitment is especially strong.

I will visit with you a little bit about the Conservation Effects and Assessment Project. I was loaned to Senator Lugar in the 2002 Farm Bill. There is a little provision in there that said, USDA, we want you to look at all these conservation practices you guys are putting on, and you tell us, are they working, are they not working. If they are not working, tell us what we ought to be doing.

So this CEAP project began in 2003. We are looking at 12 watershed basins, we will do one national report. Two of them are released, two are in the process, there are eight in the queue line. We are looking, we are finding out some results right now. One is, conservation works. If it was not for the conservation that was already applied on our land, depending on whether it is nitrogen, phosphorus, sediment, the problem would be somewhere, 30, 40, 50, 60 percent worse than it is now. So I am asking you to consider that the glass is half full.

The second thing we have learned is that there is more to be done. This mirrors what my colleagues are saying. Subsurface nitrogen has been identified as the biggest problem in three of the reports that we are ready with. In Ohio and Tennessee, it looks like phosphorus might be the one. That one is still under peer review. But without question, subsurface nitrogen and the nutrients are the big issues.

Three, we know that systems works better. Bill talked about that in his testimony, about how you have to match the practice to the landscape. And if you don't, you can actually exacerbate a problem if you don't really think through and put the right mix of practices there.

And the fourth thing we have learned is that targeting or focusing a resource really works. If we pick the right acre and treat a high impact acre, we can have 20 times the impact of treating a lower priority acre.

So that is great. The CEAP is wonderful, it has given us a lot of information. We are using it to inform our programs. But it is just a model. It is not a person, it is not a farmer, it is not going to design a system or anything like that.

So let me visit with you a little bit about how we are using it. We are targeting our Resources to identify specific problems. Senator Sessions, we are looking at the Mississippi River, the 13 States, to try to do something about hypoxia in the Gulf of Mexico. We have 43 sub-watersheds that I didn't identify. We are talking about national and local. These were identified by local people, where nutrient loadings are the biggest issue. They use the sparrow model and EPA data to identify them. We have spent $95 million over the last 2 years on nutrient management, trying to help that.

Senator Cardin, you know about the Chesapeake Bay and the amount of funding. I believe that you and some of your former colleagues were responsible for a little provision in the 2008 Farm Bill called the Chesapeake Bay Watershed Initiative. We are trying to faithfully do that. We put $126 million extra in there in the last 2 years, and it is highly focused, highly targeted to helping the Bay.

We are trying to leverage our funds. We took $20 million this year and entered into agreements with State agencies and private entities to expand our technical assistance.

I just brought this book, just as an illustration. This is one engineering plan for one confined animal feeding operation in Montana. This is the amount of technical work that has to go into it. If you want to look at the design criteria for the side pressure walls, the drainage system, the gutter design, it is all here. Men and women are who have to do this thing, so we are trying to leverage our funds so we can expand those Resources.

This year, in two of our programs, we have enrolled 25 million acres. That is three times the size of Maryland.

And just one more thing before I summarize, Ms. Stoner mentioned Grand Lakes St. Mary's in Ohio. We are not unaware of these issues. Since 2006, we have put $8 million into Grand Lake St. Mary's Ohio to try to deal with the nutrient issue. This year we also funded a conservation innovation grant that is going to be used in green energy. We are going to turn that manure into energy.

In conclusion, I would say that we certainly believe that ag is a preferred land use across our landscape. This is the land where our food comes from, our fiber. It is so important for the future, not just for us, but for those little Americans who come after us. Thanks.

[The prepared statement of Mr. White follows:]

Testimony of Dave White, Chief
Natural Resources Conservation Service, USDA
Before the U.S. Senate Committee on Environment and Public Works
Water and Wildlife Subcommittee
October 4, 2011

Good morning, Chairman Cardin, Ranking Member Sessions, and other members of the Subcommittee. I am pleased that you have given me the opportunity to describe the impressive actions USDA and its customers are voluntarily taking to improve water quality through conservation measures applied on agriculture lands. Our efforts are carried out with the understanding that how landowners manage their lands will help determine the fate of our nation's waters.

Established as the Soil Erosion Service, and later the Soil Conservation Service, our Agency's initial focus was on addressing soil erosion on America's cropland. Through science-based conservation planning and a voluntary incentives approach, great strides have been made in protecting our soil resource base. The conservation technology adopted by American agriculture has prevented disasters like the Dustbowl of the 1930's. As the Natural Resources Conservation Service, our Agency's focus has broadened to look across the landscape managed by our clients. Today, NRCS' conservation planning looks across all land uses and addresses environmental challenges in a more holistic, integrated manner. NRCS' technical assistance model allows our programs and planning services to focus on the environmental concerns of the region or watershed and to meet the objectives of our clients.

It is clear that the loss of nutrients and other pollutants to our waterways is a significant concern in many parts of the Nation. We have made strides toward addressing these concerns as evidenced by information I will give you today.

The NRCS conservation portfolio contains a broad mix of programs aimed at conservation technical assistance, environmental improvement, stewardship, easements, water resources, and snow and soil surveys. Research has shown that the conservation investments, designed by Congress and implemented by USDA, benefit farmers, ranchers and private forest landowners as well as all Americans – by helping secure a high quality environment in concert with food security for our nation and the world.

Conservation Effects Assessment Project

Over the past several years, NRCS has taken the lead within USDA to estimate the effectiveness of the Department's conservation efforts. The Conservation Effects Assessment Project, or CEAP, is a multi-agency effort to estimate the environmental effects of conservation practices and to develop the science basis for managing the agricultural landscape. In simple terms, CEAP simulates the impacts of conservation on the landscape and provides a path forward on how to improve implementation of USDA conservation programs and policies.

One of the major thrusts of CEAP has been a series of studies on the effects of conservation practices on cropland in reducing the movement of sediment and nutrients from farm fields into rivers and streams. We have released the first three regional reports in this series—on the Upper Mississippi River Basin, the Chesapeake Bay Region, and the Great Lakes Region. We have two more reports coming out on the Ohio-Tennessee River Basin, and the Missouri River Basin. We have plans to complete reports on other major river basins and water resource regions in the conterminous United States.

The CEAP cropland reports are based on farmer surveys on actual farming activities and conservation practices applied. These surveys were conducted by USDA's National Agricultural Statistics Service from 2003 through 2006. We then correlated the survey information with soils and climate information from the National Resources Inventory (NRI) sample points and statistically expanded these data to represent all cropland in the watershed. Finally, we fed the combined information into a natural resource assessment model and then eventually into a watershed model to simulate downstream outcomes of producers' activities. The models simulate environmental conditions allowing USDA to simulate the cumulative effect of conservation practices in terms of—

- **First,** reductions in losses of sediment, nutrients, and pesticides from fields;
- **Second,** enhancement of soil quality through increases in soil organic carbon; and
- **Third,** reductions in delivery of sediment, nutrients, and pesticides to rivers and streams.

The simulations provide estimates of the effects of conservation practices in place on the landscape and also help us determine treatment needs on cropped acres and assess further potential gains from additional conservation treatments.

A follow-up landowner survey will be conducted this coming winter and spring in the Chesapeake Bay Watershed. It will use approximately twice as many NRI sample points as were used in the 2003 to 2006 survey. It will provide statistical reliability of our estimates at a smaller sub watershed scale, and it will also assess the adoption of winter cover crop use on farmland, particularly in Maryland, since 2006.

The CEAP-Cropland assessment includes all conservation practices applied on the land—including those associated with federal conservation programs, supported by the states and non-governmental organizations, and those resulting from the actions of individual landowners and farm operators.

Conservation practices on cropland have been effective. Our CEAP studies show that sediment and nutrient losses from farm fields are lower than they would have been if conservation practices were not in use on those lands. Farmers' adoption of conservation practices has been especially effective in reducing erosion, sedimentation and nutrient movement from fields to waterways.

Agriculture has a disproportionate impact on the loss of sediment, pesticides, and nutrients from farm fields and subsequent loadings of these materials to local waterways. Agriculture is an intensive land use, and these environmental disturbances are a byproduct of the food, feed, fiber, and renewable energy that agricultural lands produce. However, I do not in any way suggest that agriculture cannot and should not do a better job. The water quality improvements we have experienced need to be the foundation for even greater gains in the future, and CEAP is helping us define our effectiveness and identify critical focus areas. Some themes are beginning to emerge from the CEAP-Cropland studies. I will draw upon findings from the first four regions in this series to illustrate what we have discovered in terms of sediment and nutrient loadings. The findings can be summarized as follows:

1. Agricultural conservation practices are achieving results.

Most cropland has structural and/or management practices in place to control erosion. In all four regions, some combination of these practices is in use on 94 percent or more of the cropped acres. Permanent structural practices, such as terraces, are in use in on up to 72 percent of highly erodible cropland acres that would otherwise be vulnerable to high rates of erosion. It should be noted here that the need for structural practices varies widely from region to region: For example, some 44 percent of the cropped acres in the Chesapeake Bay

Watershed are highly erodible land, compared to only 17 percent in the Great Lakes Watershed. In addition to the structural practices, reduced tillage is used in some form on more than 80 percent of the cropland in the regions we have studied so far, and in some regions reduced tillage is used on an even higher percentage of cropland.

Adoption of conservation practices has been especially effective in reducing erosion and sedimentation. In the four regions, computer simulations show that, compared to conditions that we would expect if conservation practices were not in place—

- reductions in field-level sediment losses ranged from 47 to 61 percent,
- reductions in surface losses of nitrogen ranged from 35 to 45 percent,
- reductions in subsurface nitrogen losses ranged from 9 to 31 percent, and
- reductions in total phosphorus losses ranged from 33 to 44 percent.

2. Despite the gains, we have opportunities to make more progress.

The CEAP-Cropland studies have shown us that in most places our focus when working with farmers has to be on nutrient management. In three of the four regions—all but Ohio-Tennessee—the loss of soluble nitrogen in subsurface flows is the single most critical agricultural conservation concern. To some extent, our success in reducing erosion has worked against us because by keeping water on the field we are encouraging increased infiltration of water into the soil. That water carries soluble nutrients into the soil, especially nitrogen, and most of that soluble nitrogen eventually works its way through subsurface pathways into tile drains, ditches, streams, and rivers.

More can be done to reduce nitrogen losses through complete and consistent nutrient management. This means that we need to consider the rate, form, timing, *and* method of application. In some regions, as many as 62 percent of cropped acres need some additional nutrient management to address losses of nitrogen through subsurface pathways. However, with respect to surface losses of nitrogen, acres needing treatment range only as high as 29 percent of the cropped acres. This includes improved management of manure applications, especially the timing of applications, to ensure that the nutrients in the manure are available to the crops when they need them.

3. Suites of conservation practices are needed to manage complex loss pathways.

A system of conservation practices that includes soil erosion control and consistent nutrient management is required to address sedimentation and loss of nitrogen through leaching and associated loss pathways. These systems should include a site specific prescription involving conversion to no-till, installation of field buffers, changes to the crop rotation including the addition of cover crops, and improved nutrient management.

4. Targeting the most critical acres delivers the largest benefits.

A number of factors amplify the potential for nutrients and sediment to move from farm fields, including inherent vulnerability factors such as soils prone to leaching or runoff and high precipitation levels. Targeting those acres with inherent vulnerability factors is likely to deliver the largest benefit. Treating cropped acres with high vulnerability factors can have twice the impact in terms of conservation benefits as treating the acres with low or moderate vulnerability factors. In some areas, the potential conservation benefits of targeting vulnerable acres are even greater.

In the Chesapeake Bay Watershed, significant progress in conservation adoption has been made since the completion of the last phase of the CEAP farmer survey, particularly with respect to cover crop use. Since 2006, implementation of cover crops in the watershed has increased, particularly where state programs have supported the use of cover crops. When used properly, cover crops protect the soil from erosion during the winter months, take up nutrients remaining in the soil, and release plant-available nutrients slowly over the subsequent cropping period, thereby reducing nutrient leaching and runoff during the non-growing season.

Beyond establishing a baseline of conservation programs and highlighting continued areas for improvement for the agricultural sector, CEAP has the potential to be a key tool for improving the effectiveness of our programs. NRCS is using CEAP findings to inform and improve our program implementation process and direct our conservation dollars to benefit water quality as follows:

1. Improved targeting. NRCS has established a number of initiatives that I will highlight later and improved its tools to direct its funding to address lands with the highest priority resource needs. For example we are

working to incorporate soil vulnerability information into more of our targeting efforts.

2. Suites of practices. The foundation for any suite of practices used to address nutrients will begin with the NRCS Nutrient Management practice standard. NRCS is revising our Nutrient Management practice standard making it more comprehensive and innovative. We are expanding the fertilizer industry's "4R's" mantra – of using the Right Source at the Right Time in the Right Place at the Right Rate by continuing to promote this sound approach with new and innovative technologies like precision agriculture.
3. Improved treatment of soluble nutrients. We have established a team of experts and are working closely with partner entities to increase the adoption of agriculture drainage water management (these are practices that hold drainage water in the soil over the winter to allow denitrification as well as reduce subsurface losses of nitrogen during the winter) in a focused approach in critical watersheds. The adoption of these conservation practices alone can reduce the outflow of nitrates from subsurface drainage systems by as much as 60 percent.
4. Monitoring. We developed a new practice standard for edge of field water quality monitoring to assess impacts of conservation practices. This standard was developed in consultation with our partners to ensure our data collection efforts are consistent and meaningful. Additionally, we hired objective science advisors from the academic community to conduct certain monitoring efforts.
5. Precision agriculture. Precision agriculture or precision farming is a farming management concept that recognizes and responds to variations within a field. It relies on new technologies like use of satellite imagery and sophisticated farming equipment that allows for the application of the right amount of nutrients exactly where they are needed. Farmers can locate their exact position in a field through Global Positioning Systems (GPS) and apply site-specific nutrients avoiding potential over-application in other parts of the field. NRCS has been providing financial incentives across the nation to interested producers through our Environmental Quality Incentives Program (EQIP) for a number of years.
6. Exploring opportunities. NRCS is exploring innovative approaches to address natural resource needs through potential opportunities for environmental markets.

Geographic Initiatives

The CEAP findings support the manner in which we are implementing our water quality program initiatives in priority geographic areas. I will give you some highlights of our efforts in these areas:

MISSISSIPPI RIVER BASIN HEALTHY WATERSHEDS INITIATIVE (MRBI) was implemented to improve the health of the Mississippi River Basin. This Initiative builds on the past efforts of producers, NRCS, partners, and other State and Federal agencies. NRCS and its partners are helping producers in selected watersheds voluntarily implement conservation practices and systems that avoid, control, and trap nutrient runoff; improve wildlife habitat; and maintain agricultural productivity. NRCS used Environmental Protection Agency (EPA) and U.S. Geological Survey (USGS) data and CEAP findings as part of the suite of screening tools to identify high priority areas in which to implement MRBI.

MRBI includes a monitoring and evaluation approach designed to assess environmental outcomes at the edge-of-field, in-stream, and at the watershed level. An interagency monitoring strategy is currently being proposed that would enable federal, state and NGO partners to participate in a multidimensional water quality monitoring effort. The data gathered through this effort would help us develop better adaptive management approaches at the field scale and more accurate modeling capabilities at much larger geographic hydrologic unit scales. While there are a number of factors impacting the nutrient loads into the Gulf of Mexico, NRCS conservation efforts with private landowners contribute significantly to reducing nutrient loading in the Mississippi River Basin and ultimately to the Gulf of Mexico.

CHESAPEAKE BAY WATERSHED INITIATIVE (CBWI) was authorized through the 2008 Farm Bill. The initiative was authorized to receive $188 million between FY 2009 and FY 2012. We are working with Federal and State partners to prioritize assistance to cropland where implementation of practices will have the greatest water quality benefits. NRCS used its own data and data from the EPA Chesapeake Bay Program Office, USGS, and the University of Maryland to determine where to direct the CBWI funding. This information was used to locate *agricultural areas with hig*h nutrient yields to the Chesapeake Bay and nutrient-related local impairments. NRCS will continue to look to sound science, local leadership, and partnerships to help us direct our resources to areas where they can do the most good and produce the largest benefits for water quality.

In addition, we are helping to restore the Chesapeake Bay through the establishment of three "Showcase Watersheds," – one each in Maryland, Pennsylvania, and Virginia. The concept behind the Showcase Watersheds is to demonstrate what can be accomplished by bringing together dedicated people, sound science and funding to solve natural resource problems in a priority area.

There is a strong demand for CBWI funding for projects in the Chesapeake Bay area. As of September 21, 2011 (FY11), we have developed 1,706 contracts with CBWI funds. Yet, we have more than 560 unfunded applications requesting CBWI funds.

USDA is working with EPA and States on a certainty framework that would encourage farmers to implement a suite of voluntary conservation activities that reduce impacts on water quality. States would develop programs that can provide assurances that the farmers' activities are consistent with State plans to improve water quality, such as the objectives of a State's TMDL Watershed Implementation Plan (WIP).

WEST MAUI CORAL REEF INITIATIVE (WM-CRI) is designed to control land-based pollution threats to coral reefs in the Ka'anapali-Kahekili watershed of Hawaii. The health of living coral reefs is dependent upon superior water quality and clarity allowing effective sunlight penetration. The primary threats to this watershed include sediment deposition, nutrients, and other pollutants which are transported in surface water runoff and groundwater seepage into coastal waters. NRCS is working with agricultural producers and other non-federal land managers to address soil erosion and soil health, water quality and conservation, air quality, healthy plants, energy conservation, global warming issues, and upland and wetland wildlife habitat enhancement.

The goals of this initiative are: 1) to reduce pollution to improve coastal water quality and coral reef ecosystem health; 2) to improve coordination between federal and state agencies, land managers and marine scientists; 3) to improve knowledge of how land management affects coral reef health; and 4) to increase awareness about water quality, pollution prevention, and control measures.

GREAT LAKES RESTORATION INITIATIVE (GLRI) targets the most significant environmental problems in the Great Lakes Basin. These problems include toxic substances and areas of concern, invasive aquatic and terrestrial species, near-shore and non-point source pollution, and habitat and wildlife protection and restoration. NRCS worked with EPA to identify priority watersheds for nonpoint source pollution reduction.

In FY2011, NRCS received over 600 applications for assistance under GLRI and currently has obligated over 390 contracts totaling over $18.7 million under the reimbursable agreement with EPA. Most of the contracts focus on reducing nutrient and sediment loads from private lands, combating invasive species, and improving wildlife habitat.

CEAP-Wildlife Findings

While we are on the subject of CEAP, I want to emphasize that CEAP is more than a series of cropland studies. CEAP also has components for analyzing grazing lands, including rangeland and pastureland; wetlands; and wildlife habitat. There are also CEAP studies at the watershed scale to validate broader scale findings.

A number of the CEAP-Wildlife studies have been released, but I would like to emphasize one that was carried out in Montana, where I worked for several years and which Senator Baucus represents. In this study, the response of wild trout to reach-scale stream improvement from 1989 to 2009 was examined primarily on private ranchlands in Montana's Blackfoot River Basin. Population densities were estimated to examine the response of native and non-native trout to conservation practices on 17 streams.

Three years after restoration treatment, total trout density increased 59 percent from pre-treatment conditions. In fact, trout densities approached those of relatively undisturbed reference streams. Improvements in most streams were followed by increasing and sustained trends in total trout density.

Stream restoration efforts have resulted in the expansion of native fish populations, including the west-slope cutthroat trout, across several tributaries and within the main stem of the lower Blackfoot River. This particular trout species is important because it is a candidate for listing under the Endangered Species Act.

Other examples where we are using a landscape level approach to addressing resource concerns include NRCS wildlife initiatives:

MIGRATORY BIRD HABITAT INITIATIVE (MBHI)

The Migratory Bird Habitat Initiative (MBHI) has proven to be very successful in providing critical habitat in a way that also provides significant water quality benefits. In response to the Deepwater Horizon oil spill in the Gulf of Mexico last year, NRCS quickly launched the MBHI to help landowners develop alternative habitats for migrating and wintering waterbirds. NRCS worked with owners and operators of private croplands, catfish ponds and Wetlands Reserve Program easements throughout the Mississippi Alluvial Valley and Gulf Coast regions and NRCS provided assistance developing shallow water and mudflat habitats to make moist soil, plant seeds and tubers, waste grain and invertebrate foods available. In the wake of the oil spill and during the severe drought conditions along the Gulf Coast in 2010, landowner response to the initiative was overwhelming, with over 470,000 acres enrolled. NRCS was able to assist private landowners with providing wetland habitat at a critical time in Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, Missouri, and Texas. The enrolled lands were heavily used by migrating waterfowl and shorebirds. The MBHI also helped mitigate some of the damage caused by the oil spill, as well as combat drought conditions and decades of wetland losses in the area.

NRCS initiated a three-year effort with partners, including Mississippi State University, to determine the initiative's effectiveness through monitoring the number and species of birds which utilize the habitat created.

Preliminary estimates reveal that the enrolled acres provided up to 36 percent of the food energy needs of the over 9 million ducks that winter in this area. MBHI is also very cost-effective. For example, the $5.2 million MBHI expenditure in southwest Louisiana resulted in a calculated 475.7 million duck-energy days, or about 1 cent per duck-energy day. A duck energy day is the amount of food energy needed to sustain an average sized duck for one day. For comparison, the estimated cost of feeding an average-sized duck a commercial maintenance diet in captivity is about 4 cents per day, which is nearly 4 times greater than the estimated cost of a duck-energy day delivered through MBHI.

MBHI is demonstrating the potential for agricultural lands to remain productive while simultaneously providing needed habitat for wildlife. As a result, NRCS is extending the initiative north to improve migratory bird habitat in nesting areas.

Other examples where we adopted a landscape level approach to addressing wildlife issues in a manner that also provides significant water quality benefits include:

NORTHERN PLAINS MIGRATORY BIRD HABITAT INITIATIVE (NP-MBHI)

NRCS has a longstanding commitment to supporting wildlife in the Prairie Pothole Region and throughout the rest of the US. In 2011, NRCS implemented the Northern Plains Migratory Bird Habitat Initiative (NPMBHI) through its working lands conservation programs. This collaborative effort aims at restoring working lands to wetlands; managing farmed wetlands to minimize impacts on wildlife and water quality; and, maintaining existing wetlands. In addition to providing habitat, improvements to the region's wetlands will reduce the nutrients and sediment in the waters of the initiative area.

The initiative covers approximately 100,000 square miles, including portions of Iowa, Minnesota, Montana, North Dakota, and South Dakota. The region supports more than 50 percent of North America's migratory waterfowl, and over 300 bird species rely on the region during migrations.

NEW ENGLAND-NEW YORK FORESTRY INITIATIVE

The forests of New England and New York cover 52 million acres, including the largest intact block of temperate broadleaf forest in the country. The forests are the backbone of the rural economies providing a sustainable source of renewable energy, forest products, tourism, outdoor recreational opportunities, and clean water.

The New England/ New York Forestry Initiative has allowed seven states (Connecticut, Maine, Massachusetts, New Hampshire, New York, Pennsylvania, Rhode Island, and Vermont) to undertake a regional approach to address forest ecosystem health.

Strategic Watershed Actions Teams (SWAT) funded through the initiative will dramatically increase protection and restoration of forests and provide water quality benefits. For example, in Vermont, it is estimated that the teams will increase forest management plan development and implementation, increase habitat for upland species, and reduce soil erosion by 41,000 tons over the next 3 years, decreasing the sediment and phosphorus reaching Lake Champlain by 29,000 tons and 39,000 pounds, respectively.

Summary

There is a sense among the agricultural community that these are uncertain times for farmers. The public is increasingly interested in knowing the results of our program expenditures. Our CEAP effort will help us target program funds to the places and the practices that have the greatest impact on nutrient and sediment loadings to waters, as well as addressing other natural resource concerns. With assistance from key partners in critical watersheds, we have developed new approaches, such as Strategic Watershed Action Teams, that we believe will engage additional producers to accelerate conservation adoption on private lands. Through new planning tools, we will integrate the technology developed through CEAP at the farm level to help clients understand the conservation benefits from recommended practices and make science-based decisions. In addition, USDA is actively working with EPA and the states to explore a framework for engaging producers in conservation activities while providing regulatory certainty to producers. With our resources, the resources of our partners, and the resources of producers themselves all leveraged toward improving water quality, USDA sees the agricultural community as taking a proactive approach to addressing water quality issues of this nation.

I appreciate the invitation to be here today and I am happy to answer any questions.

Senate Committee on Environment and Public Works

Hearing on Nutrient Pollution: An Overview of Nutrient Reduction Approaches

October 4, 2011

USDA Response to Questions for the Hearing Record

Questions from Senator Benjamin Cardin:

1. **We heard testimony at the hearing on how agriculture is a significant contributor to the nutrient pollution problem. Additionally, non-point source pollution is challenging to address because the agricultural sector contributes a substantial proportion of the overall nutrient pollution. What are some of the things that USDA is doing to mitigate nutrient pollution from agriculture?**

USDA's Conservation Effects Assessment Project (CEAP) Chesapeake Bay study, released in 2010, evaluated the impact of agricultural conservation practices on cropland in the Chesapeake Bay watershed. The study found that farmers are reducing nutrient and sediment runoff through the use of voluntary, site-specific conservation practices. For example, the study found that conservation practices on the ground have reduced surface nitrogen runoff by 42 percent (when compared to a baseline of no conservation practices applied). CEAP also found that almost 90 percent of farmers in the Bay watershed are using some form of reduced tillage, a remarkable finding. These findings are similar in other large watersheds that CEAP has covered.

That being said, cultivated cropland contributes disproportionately to sediment and nutrient pollution in the Bay. Although cultivated cropland makes up only about 10 percent of the land area of the watershed, the study estimated that it contributes 22 percent of the sediment, 31 percent of the nitrogen, and 28 percent of the phosphorus to the Bay. The CEAP study concluded that that ample opportunity exists to reduce sediment and nutrient losses from cultivated cropland. Cultivated cropland, however, is neither the only nor the largest contributor of these materials to the Bay. Simulating runoff from non-cropland and incorporating point source data provided by the Environmental Protection Agency (EPA), the Natural Resources Conservation Service (NRCS) estimates that urban land, which makes up 8 percent of the watershed area, contributes 40 percent of the sediment, 38 percent of the nitrogen, and 50 percent of the phosphorus to the Bay. All sectors have a critical role to play in achieving pollution reductions that will produce a healthy Chesapeake Bay.

CEAP also highlights that opportunities exist to further reduce sediment and nutrient losses from cropland. In particular, stemming subsurface nitrogen losses remains our biggest challenge in many places around the country. Following are examples of recent steps NRCS is taking to help producers reduce losses of sediments and nutrients from farm fields:

- Targeting—in the Chesapeake Bay, Great Lakes, and the Mississippi River Basin, NRCS has developed water quality initiatives to target funding to those places and practices where it will do the most to help reduce nutrient and sediment pollution.
- Strategic Watershed Action Teams—in fiscal year 2011, NRCS dedicated $20 million for Strategic Watershed Action Teams (SWATs), composed of technical experts that work in NRCS initiative areas. NRCS was able to leverage the $20 million with matching contributions from nongovernmental, State and local partners. These teams are charged with helping accelerate conservation adoption in places where additional technical assistance can have a significant impact on water quality improvement.
- Nutrient Management Standard Revision—NRCS has revised its 590 Nutrient Management conservation practice standard to emphasize the importance of coordinating conservation practices designed to avoid, control, and trap nutrients before they leave the field. The standard reinforces the fertilizer industry's "4Rs" approach to nutrient application planning. That is, nitrogen and phosphorus need to be applied in the right amount, from the right source, at the right time, using the right method of application to minimize the risk of nutrient losses to local water. As CEAP shows, if any one of the 4R factors is not followed, then the risk of nutrient loss may increase and nutrient use efficiency may decrease. The revised standard also incorporates adaptive nutrient management for the first time. Phosphorous Risk Assessment Tools—NRCS has revised its nutrient management policy to encourage states to improve their phosphorus risk assessment tools and to help standardize the interpretation of tool results across jurisdictional boundaries. That is, similar levels of risk should stimulate similar treatment strategies across state boundaries or in different watersheds.

- Agricultural Certainty—NRCS is working with EPA to support a number of States in encouraging the development of Agricultural Certainty programs. These programs would encourage producers to implement voluntary conservation practices in exchange for assurances that, for a reasonable, fixed period of time, these actions will be recognized as consistent with state plans to improve water quality. NRCS believes such programs could help accelerate conservation adoption in critical watersheds.
- Water Quality Trading—USDA is supporting the development of water quality trading markets in the Chesapeake Bay and Ohio River watersheds. Such markets could bring new sources of investment into agricultural conservation.
- Conservation Innovation Grants—NRCS continues to invest in new technologies and approaches to nutrient management and sediment control, including manure-to-energy and precision agriculture technologies.

There is no silver bullet to mitigating nutrient and sediment losses from farms. USDA and its partners are working in countless ways on the issue, from traditional sediment control and nutrient management strategies, to new approaches throughout the country. Our investment in edge-of-field monitoring and modeling efforts like CEAP will help us validate the effects of these efforts in the years to come.

2. **There is interest in new tools and options for addressing nutrient pollution from agriculture. One such potential tool is the idea of nutrient credit trading. I introduced one such approach last year as a component of legislation to improve water quality in the Chesapeake Bay. Do you think a nutrient-trading program would be an effective way to manage and reduce nutrient pollution? Why or why not?**

   USDA supports the idea of nutrient credit trading as an important and cost-effective tool for achieving water quality goals in the Chesapeake Bay and is coordinating with the jurisdictions and our federal partners to advance this approach. Some recent studies of the costs of meeting TMDL allocations in the Chesapeake Bay Basin indicate that reducing nutrient loss from agriculture is less expensive than achieving the same reductions through storm water management or other technological improvements from point sources. A recent study by the World Resources Institute (WRI) found that a Bay wide nutrient trading program could reduce nutrient removal costs in the waste water treatment sector by as much as 69 percent. From a markets perspective, EPA's development of a TMDL for the Bay is a positive advance, as it provides the missing link of a nutrient cap, essential for the formation of a market.

There are a number of conditions that need to be met in order for nutrient credit trading markets to be effective. Among these are the development of an infrastructure to match buyers and sellers, ensuring an adequate supply and demand for trading, defining the unit of the credit being traded and quantifying its impact on targeted water bodies are key conditions, and the coordination of state and federal policies and programs.

The uncertainty surrounding the measurable reductions in nutrients achieved through changes in agricultural practices and land management reduces the potential supply of credits and the savings that can be achieved through trading. That is why USDA is developing metrics and reporting tools, such as the Nutrient Tracking Tool, to quantify the reduction in nutrient loss achieved through changes in agricultural management and land use.

USDA wants to help build a more transparent credit market that facilitates participation in trading. Through a Conservation Innovation Grant with WRI, NRCS is supporting development of a Chesapeake Bay-wide nutrient credit trading platform. WRI is working with the States in the region and with USDA to create a suite of web-based tools used to facilitate nutrient credit trading.

While progress is being made in establishing nutrient credit trading as a cost–effective tool , challenges remain, such as addressing differences among current state trading programs, questions of liability when nutrient-reducing activities of nonpoint source providers fall below expected reductions, and tracking and monitoring nutrient reductions. With experience and on-going adjustments to supporting hydrologic models and nutrient trading programs, these challenges should be overcome over time.

In several States that are developing nutrient credit trading markets, USDA is encouraging the development of Agricultural Certainty programs. Agricultural certainty programs, by establishing a baseline of conservation activity for producers, may help reduce transaction costs and eliminate other barriers to the successful deployment of nutrient credit trading markets.

3. **You were very optimistic last spring when you testified to the House Agriculture Committee on nutrient management in the Chesapeake region. Do you continue to have confidence that the public-private partnership in restoring water quality in the Chesapeake Bay can be successful?**

Yes. Monitoring data tells us that we are on the right track and that our efforts to reduce pollution are making a difference. A study by Johns Hopkins University and the University of Maryland Center for Environmental Science (UMCES) found that mid- to late-summer dead-zones in the Bay have decreased since the 1980s, reflecting the regional partnership efforts to reduce nutrient losses.

Restoration of water quality in the Chesapeake Bay will not occur without a concerted effort across all sectors and interests. At USDA, we work closely with federal agencies, state and local governments, nonprofit organizations, universities, and of course, private landowners to collectively take steps forward in improving water quality in the Bay watershed. Agricultural producers have made great strides in improving water quality, and it is one of the few sectors that has consistently reduced nutrient and sediment loads since 1985. We know that Bay watershed farmers can do more, and USDA's conservation partnership has the tools and incentives to help.

4. **You have provided us with data about your findings regarding farming's contribution to nutrient pollution. Do you believe nutrient pollution, based on your data, is a problem that the federal government should continue working to address?**

Yes. USDA agrees that addressing nutrient pollution will require dedicated efforts by all parties, including the federal government, States, farmers, municipalities, and others. The federal government has an important role to play in Chesapeake Bay restoration as the watershed spans six States, two of which border the Bay. Multi-State natural resource issues, require a coordinated approach. USDA works closely with the many partners in the watershed to find solutions to nutrient pollution challenges, and it is not a stretch to say that USDA agencies are woven into the fabric of addressing the nutrient pollution challenge in the Bay watershed.

Within the Chesapeake Bay, USDA is working collectively with other federal agencies under Executive Order 13508 to improve the health of the Chesapeake Bay. The Executive Order has granted occasion for the relevant federal agencies to assess their own Chesapeake Bay activities and look for opportunities to gain efficiencies and new approaches through working with other agencies. USDA remains committed to this ongoing collaboration across the federal government.

5. **How have USDA and EPA worked together in controlling nutrient pollution? Should these two agencies continue to collaborate?**

USDA has been collaborating with EPA on nutrient issues for well over a decade, and is committed to working with EPA and with the Bay states to help ensure that farmers can continue producing food and fiber while improving the health of the Bay. Executive Order 13508 directed federal agencies to develop a federal strategy for restoring the Chesapeake Bay. Released in May 2010, the strategy outlines how USDA, EPA, and other federal partners will work together improve Bay water quality. Below are a number of ways that USDA and EPA are working together in the Chesapeake Bay watershed:

- USDA used nutrient and sediment data from EPA and U.S. Geological Survey (among other sources) to help identify priority watersheds used for targeting funding through the Chesapeake Bay Watershed Initiative.
- USDA and EPA are working with a number of stakeholders to develop a system of accounting for conservation practices implemented by farmers without financial assistance from federal or state sources.
- USDA and EPA developed a workplan that outlines opportunities for collaboration on modeling the agricultural sector in the Bay watershed.
- USDA and EPA are working with Bay States in support of development of Agricultural Certainty programs.

- USDA and EPA, along with other federal agencies, are supporting States as they work to create the infrastructure for ecosystem services markets.

Executive Order 13508 reaffirmed EPA as the lead federal Agency for Chesapeake Bay restoration efforts. USDA will continue to collaborate with EPA and other federal and state partners to improve water quality in the Bay watershed where our policy and programmatic goals and priorities overlap.

Questions from Senator James Inhofe:

6. **Do you stand by the NRCS CEAP report on agricultural impacts on the Chesapeake Bay? Do you believe it is accurate?**

   Yes. The study design, data, and modeling have produced results that are appropriate for decisionmaking pertaining to conservation program design and implementation at the national and regional scales, including the Chesapeake Bay Basin.

   Conclusions drawn from CEAP reports are generally limited to large basins (4-digit Hydrologic Unit Code regions, such as the Susquehanna and Potomac River watersheds). Specifically, the CEAP study shows that most cropped acres in the Chesapeake Bay watershed are under-treated relative to their potential for runoff or leaching. Because of the statistical design and farmer survey sample size, the CEAP report does not attempt to assess conservation treatment needs for small, local areas. However, a variety of tools, such as the revised universal soil loss equation (RUSLE) and phosphorus and leaching indexes, are available to assist in guiding farm-scale conservation planning to address treatment needs. Through the Conservation Delivery Streamlining Initiative (CDSI) NRCS will incorporate tools and models into the Field Office conservation planning applications to improve planning and emphasis on natural resource benefits.

7. **The Scientific and Technical Advisory Committee to the Chesapeake Bay Program has agreed that a model cannot be used to make precise allocations in a TMDL, and "no TMDL has or will ever likely obtain such accuracy, and most watershed modelers would concur that such a goal**

is folly." The Committee also said, "The acres of conventional tilled acres versus conservation tilled acres vary considerably between the two reports and this concern is legitimate." Are these issues-the inability to use a model to make individual allocations and the discrepancy in the number of acres in conservation tillage true? Considering these statements, how can NRCS help EPA target the most cost effective measures to reduce nutrient loadings to the Bay? How can the CEAP data be used to help agriculture make further progress in the Bay, if the allocations are locked in by the TMDL?

The strength of CEAP sampling and modeling is in defining the extent to which the use of conservation practices can reduce the loads delivered to rivers and streams within the Chesapeake Bay watershed without changing the mix of crops grown or the extent of cropped acres. CEAP modeling can identify the type of acres that are most in need of treatment to increase the efficiency of conservation program implementation in the region. It can also estimate the reductions in sediment and nutrient losses that we would expect to occur if we were to target additional conservation treatment where it is needed most.

USDA's CEAP Model and EPA's Bay Watershed Model were built for different purposes and use different modeling platforms. It is no surprise that their outputs contain differences, and making direct comparisons between the two is technically difficult. In looking at the two models, however, both USDA and EPA agree that reconciling some notable discrepancies, such as the amount of cropland acres under conservation tillage, would strengthen the Bay Model. To that end,. USDA and EPA developed a workplan on Chesapeake Bay watershed modeling collaboration. The workplan describes how USDA and EPA will share information and techniques to strengthen modeling of the agricultural sector in the Bay watershed.

8. **Did EPA use the Chesapeake Bay TMDL to direct who needs to reduce nutrients, and how those reductions are to happen, instead of just identifying the total maximum daily loads that can enter the Bay? How is this restricting NRCS's ability to work creatively with states and local governments in achieving the goals of the TMDL?**

The development and implementation of the Chesapeake Bay TMDL, including the role of the Chesapeake Bay jurisdictions in determining sector allocations and strategies for reducing nutrients, is best described by EPA. The Chesapeake Bay TMDL has not hampered USDA's ability to work with States and local governments to reduce farm level nutrient and sediment loadings in the Bay watershed. In fiscal year 2009, long before the TMDL was released, NRCS embarked on an effort to target its Chesapeake Bay Watershed Initiative (CBWI) Farm Bill funding to priority watersheds, those areas where additional conservation treatment would yield the greatest benefit. We worked closely with states and local conservation districts to identify these priority watersheds. Later, as the Bay States began developing their TMDL Watershed Implementation Plans (WIPs), we engaged with the States to ensure that, to the extent possible, we are aligning our Farm Bill program funding and technical assistance with State WIPs. In 2010, USDA in collaboration with Maryland, Pennsylvania, and Virginia identified Showcase watersheds to demonstrate new methods for accelerating conservation implementation.

9. How resource intensive is developing a scientifically sound conservation plan for a farm?

NRCS conservation planners work closely with the client to identify natural resource problems and opportunities that may exist on a farm and determine the clients' objectives for the conservation plan. Planners spend time on the farm to inventory all land uses for soil, water, air, plant and animal resource concerns. Planners use published soil, topographic, hydrologic and other natural resource information available for the farm to determine where problems may exist. Tools and models are then used to determine the extent of potential losses of soil and farm inputs due to erosion, runoff, and leaching as well as taking into account other resource concerns such as improvement of wildlife habitat air quality, and energy conservation. The client provides information for the farm, such as crop yield, management practices and inputs that are used in the analysis. Based on the resource concerns identified during the inventory and analysis phase, planners formulate alternatives, and works with the clients to select the best alternative based on the client's objectives. This selected alternative forms the basis for the conservation plan and includes conservation practices the client can implement to address the resource concerns identified in the plan.

Time spent in developing a conservation plan can vary based on several factors such as operation size, land use, number of fields, management complexity, and type of operation. A more complex Comprehensive Nutrient Management Plan can be developed for an animal feeding operation if that is identified as a need in the conservation plan. These plans are more resource intensive because they plan for the storage, manipulation, treatment, and allocation of manure and other nutrients to farm fields in accordance with a nutrient management plan.

Questions from Senator David Vitter:

10. Have you heard from the livestock industry on the proposed changes? What are their concerns and are those concerns valid based on the proposed standard?

Yes, in response to publishing the draft Conservation Practice Standard (CPS) 590, nutrient management, in the Federal Register many responses were received from livestock industry advocates, and private beef and dairy producers. Many felt the draft was too restrictive regarding how manure nutrients can be allocated to agricultural fields. By far, the major concern raised was the banning of manure application to frozen, snow covered or saturated fields. Of lesser, but significant concern was the proposal to ban manure applications when soil nutrient concentrations exceeded 10 times the concentration needed to successfully grow the planned crops. In the course of revising the draft rule for final publication, NRCS has addressed a number of the concerns raised by the livestock industry.

Many nonpoint source nutrient problems can be addressed by doing a better job with nutrient management on a field-by-field basis. Conservation Effects Assessment Project (CEAP) studies in the Upper Mississippi, Chesapeake Bay, and Great Lakes regions clearly indicate the need to coordinate conservation practices in an effort to avoid, control or trap nutrients before they leave the field. The revised standard provides fair and reasonable criteria for protecting water quality while addressing issues important to both grower and conservation communities.

11. Can you address the following concerns that have been raised by those in the cattle business:

a) Forbid Manure Application on Soils with 10X Soil Test Phosphorus Level: It is inappropriate to impose an arbitrary cutoff level for soil phosphorus. Instead, states should be encouraged to implement effective risk-based assessments for P. The P Index provides this assessment by evaluating scientifically the source and transport issues for each field. A 10X soil test P level is

arbitrary and not correlated to water quality concerns since it is only a source-based threshold, and does not address transport potential.

The 10X paragraph was removed from the standard in favor of site-specific phosphorus risk assessment tools. These state-based tools are typically developed and maintained by the local land grant university and they make use of local soil, climate and industry type data. The revised standard gives states some flexibility in determining when a risk assessment is required and when exceptions to the requirement are allowed.

b) **Forbid Manure Application on Soils with 10X Soil Test Potassium Level: Potassium is abundant in many soils across the US. Where manure has been applied, soil is likely to exceed 10X.**

The 10X paragraph has been removed from the standard. Because potassium is more a feed management problem than a water quality problem this restriction has also been removed from the nutrient management standard. We still recommend that planners avoid gross nutrient imbalances to avoid animal nutrition problems.

c) **Forbid Manure Application on Frozen and/or Snow-Covered Soils: In some areas of the country, application to frozen/snow covered grounds is essential for proper manure management. Management practices should be implemented.**

The objective of nutrient management planning is to make efficient use of available nutrient resources (commercial fertilizer, wastewater, organic by-products, manure, etc.) to grow crops with minimal impact on the environment. For animal feeding operations (AFO), comprehensive nutrient management plans help operators coordinate generated volumes of these materials with available storage capacity and spreadable acreage, and. Alternately, nutrient management plans allow for export of manure off-site to help prevent the over application of surplus nutrients.

The application of nutrients to frozen, snow covered or saturated fields is precluded in the previous and the revised standard However, the revised standard is more flexible in that exceptions may be made when specified conditions are met and adequate conservation measures are installed to prevent the off-site delivery of nutrients. The adequate treatment level and specified conditions for winter applications of manure must be defined by NRCS in concurrence with the water quality control authority in the State. At a minimum, the following site and management factors must be considered:

- Slope,
- Organic residue and living covers,
- Amount and form of nutrients to be applied, and
- Adequate setback distances to protect local water quality.

d) **Forbid Manure Application during Periods of Winter Dormancy: Proper application during winter dormancy, with management practices in place, may be the best time to apply nutrients to allow for mineralization to occur prior to active growing season.**

The winter dormancy restriction has been removed from the standard. The objective of nutrient planning is to provide nutrients for plant production with minimal negative impact on local water quality. Soil type, landscape position, proximity to adjacent waterways, application rates and frequency of application are important factors in accomplishing this objective. The standard strongly encourages timing the application of nutrients, or high mineralization rates, with periods of high crop uptake of nutrients. Plant uptake reduces the vulnerability of excess nutrients transport by surface or subsurface drainage water to local water bodies.

e) **Forbid Manure Application during Seasons of High Runoff Potential: Provision is not defined. Manure application is day to day management decision and cannot be scheduled by the Farmer's Almanac.**

The high runoff potential concept was considered too difficult to interpret and was dropped from the standard. Runoff is one of a number of site and transport factors that will be used in the assessment of potential risk for nutrient loses by surface or groundwater.

f) **Forbid Application When the Top Two Inches of Soil Are Saturated: Could prevent the application of wastewater by center pivot irrigation system.**

Soil saturation is an important indicator used to predict the loss of nutrients by surface of ground water movement. The revised standards give the states flexibility in determining circumstances that pose low, moderate or high risk to local water quality. States can also recommend additional conservation measures to help reduce the risk of loss of nutrients in solution.

g) The P Application Rate is Pre-determined to be "equal to the recommended phosphorus application, or estimated phosphorus removal in harvested plant biomass ..." Again, this is an arbitrary cut-off and is not based on the scientific assessment which is at the core of the PI. Fields on which moderate amounts of manure have been applied over past several years would receive a lab recommendation for P of "ZERO" and the crop removal rate will be in the range of 20-80 lbs of P205. Beef cattle manure application rate would be 2-3 tons manure per acre -not feasible for manure spreaders. Use of the PI is essential.

Manure allocation rates will be based on a site-specific assessment of risk for nitrogen and phosphorus loss to surface and subsurface water. The revised standard allows states to grant exceptions to the requirement for a risk assessment under certain conditions. The Phosphorus Index will assign the relative risk for P loss based on multiple site and transport factors. The determined level of risk will dictate when nutrients are to be allocated on an N-basis, P-basis or at crop removal rates. Under high risk conditions a drawdown strategy will need to be in place and additional conservation measures may be needed to reduce risk to the environment.

h) It is essential that NRCS get the 590 standard right since the standard is a required component of the nutrient management plan portion of many state Clean Water Act NPDES permit programs. What economic analysis have you done on the cost to producers of this proposed standard?

The 590 standard is developed by NRCS solely as a technical standard to help growers apply nutrients with minimal impact on the environment. The only economic analysis that incorporates the 590 standard is as a subcomponent of the Benefit-Cost Analysis for Comprehensive Nutrient Management Plans (CNMPs). This analysis is intended to determine whether the environmental benefit generated by implementation of these plans justifies the cost to the Federal government in developing CNMPs for producers. NRCS only creates CNMPs at the request of a producer and implementation by the producer is voluntary. States or other regulatory authorities are free to use standards developed by NRCS in regulations.

Senator CARDIN. Thank you for your testimony. I thank all three of you for your testimony.

I think there is general consensus that the danger of excessive nutrients caused by pollution in our waters of America, creating dead zones and a risk to public health. It is interesting, we have an example that Senator Inhofe gave us, so we now have a specific example of the danger to our health. I think it points out the need for us to be more aggressive in this area.

Mr. White, I appreciate your mentioning the Chesapeake Bay and the Farm Bill, the programs that were placed to deal with the nutrient pollutants coming from our farmers. It has been a very effective program, we thank you very much. We need more help, that is why last year I suggested a nutrient trading program, which we think also would help our farmers in giving them a financial reward to do better and help us attain the overall objectives that we think are achievable in reducing nutrients that flow into the Bay.

I might also point out, I met with local officials today from Maryland, who pointed out to me that there really isn't much help out there to deal with storm runoff. We had suggested a special program within the Chesapeake Bay program last year to help us deal with storm runoff.

Which really leads me, Ms. Stoner, to the first point, and that is, we do have direct ability to control the applications for direct point source pollution, dealing with nutrients. But non-point pollution, we do not. And the two large sources of nutrients going into our water supply come from farming activities that are not regulated, and from runoff, storm runoff, which is not regulated.

That presents a real challenge as to how we can bring those sources of pollutants into an overall scheme without the direct ability to control their activities.

Ms. STONER. Yes, Senator. Your description is correct about the authorities that we have. Of course, we also do have municipal separate storm systems, which are stormwater sources, that are under the Clean Water Act permitting program.

But we believe in using the full suite of tools that we have available to address nutrient pollution. Our approach, which I set forth in a memo last spring, is really to work with States on developing State-wide nutrient reduction strategies. Those strategies look at the loads of nutrients, what the sources are, and evaluate the full suite of tools that can be applied, whether it is grants, whether it is loans, whether it is technical assistance, whether it is regulatory tools, like a permitting program. Trading was mentioned, that is often a great tool. And other kinds of incentives that can be used.

And using the full suite together, we think that we can do a lot better job in addressing nutrient pollution.

Senator CARDIN. Mr. White, do you have a view on the nutrient trading program as an effective tool?

Mr. WHITE. I know a lot of farmers and ranchers, Senators. I haven't met one yet that is bent on world domination. I think they just want to raise their families, pay their rent, see their kids off to school. And anything we can do in this what you are describing that would help them stay in business, put money in their pocket and improve the environment, I think we should support 100 percent.

Senator CARDIN. Thank you.

Ms. Stoner, there has been at least a question raised by Senator Inhofe as the burden of numeric nutrient standards as compared to a narrative water quality standard. Could you just briefly comment on why EPA has used the numeric nutrient standards? And as I understand it, in Florida, I believe you offered to allow the locals tremendous input in developing what was right for Florida on the numeric standards. Could you just briefly describe that to us?

Ms. STONER. Yes, sir. Both USEPA and many States have indicated that they find numeric nutrient standards to be easier to implement. They set a particular target. It is like playing football and trying to figure out where the end zone is. You want to know where you are going. And they help set that standard, based on science, indicating what the water body needs in order to be healthy.

So that helps in all kinds of ways, talking about loadings and targeting of resources, helps with all kinds of different approaches to address nutrient pollution. So we do find that those are helpful and those are encouraged in the memo that I referred to earlier. We are looking at how those can be used, often along with other approaches as well, and actually have a workshop with States, starting tomorrow, to discuss those approaches.

It is not the only approach, but it is often a very effective one.

Senator CARDIN. Mr. Werkheiser, just briefly, is there a different approach needed to deal with the nutrient problems on groundwater as compared to the surface?

Mr. WERKHEISER. I think the best management practice that you would apply to the groundwater would be different than applied to surface water for a couple of reasons. One is just the length of time that the groundwater is in the system. And I think more importantly, we need realistic expectations, that this is a long-term issue. It is not something we are going to solve overnight, especially within the groundwater pollution. Those issues can last for decades.

Senator CARDIN. Senator Sessions.

Senator SESSIONS. Thank you.

Mr. White, one thing I became convinced with, as the Bay Watch advocates in Mobile Bay were engaged, and that is that discrete, special acreages or areas are often the biggest polluting sources, and that carefully targeted regulations can produce real benefit without over-regulating areas that may not be noticeable contributors. From my understanding of your initial remarks, do you believe that would be an effective way to maximize our ability to reduce runoff and nutrients in the water?

Mr. WHITE. No, sir. If I implied that, I apologize. What I meant is taking the voluntary incentive-based programs and through ranking criteria, through outreach, targeting the funds to the voluntary programs to those high areas. I am not a regulatory agency.

Senator SESSIONS. But do you conclude, as I have observed, that in an area all around a water or estuary, that there are some specific areas that are far more problematic for the health of the water than others? And that a good regulation would target and focus on those that are most dangerous? Or you would just regulate everybody and make everybody in the whole region comply with your rule, regardless of the cost and benefit?

Mr. WHITE. I would again——

Senator SESSIONS. You are not a regulatory——

Mr. WHITE. We do not have regulatory power, nor are we seeking any regulatory power.

Senator SESSIONS. Maybe I should ask Ms. Stoner that. That would be fair enough.

Mr. WHITE. That would be good with me.

[Laughter.]

Senator SESSIONS. You have to see the farmers eyeball to eyeball more than she does, I guess.

Mr. WHITE. Every day.

Senator SESSIONS. Ms. Stoner?

Ms. STONER. Yes. Certainly we believe in looking at where the loadings are coming from and focusing attention on the greatest loads. That is the way to achieve the most, we certainly agree with that point. As Senator Cardin noted in his first question to me, there are some regulations that apply to some types of entities and not to others.

So there are not regulations that apply to everyone. We have to look at different tools for different sources, and we do the best we can in putting those together to achieve the goal.

Senator SESSIONS. Is there a difference between nutrient pollution and silt runoff? Ms. Stoner, would you like to answer that?

Ms. STONER. I would, although I note that I am not a scientist. So my colleague at USGS may be able to do it in more detail.

Silt often is a carrier of nutrient pollution.

Senator SESSIONS. Is it defined in statute in any way differently?

Ms. STONER. The science really defines what nutrient pollution is, the nitrogen and phosphorus. And those compounds really come from the science. That is what we look to in terms of deciding what is too much. Because as I believe Senator Inhofe noted, having some nutrients in the waterway is normal. The question is, how much is too much, and that is what we look to the science to answer.

Senator SESSIONS. Florida filed, in April, a petition with EPA asking it to abandon its takeover of Florida's nutrient pollution program. They have a program that they worked on. Florida asked EPA to respond within 30 days. Is it correct that you have not yet answered their petition?

Ms. STONER. We did sent them correspondence in response to their petition. We are continuing to work closely with the State of Florida on developing standards that would enable us to withdraw our standards. If Florida were able to promulgate final, approvable standards, we would then remove ours. And we would very much like to be in a position to do that.

Senator SESSIONS. Well, on September 21st, 20 members of the Florida congressional delegation, including Senator Rubio, officially asked EPA to "withdraw its decision to impose numeric nutrient criteria in Florida, and place Florida on a level playing field with other States.' The delegation also asked EPA to grant the April 22d petition.

When do you anticipate giving Florida a yes or no to this?

Ms. STONER. We are on continued discussions with Florida.

Senator SESSIONS. They have asked for an answer. Will you continue to press to take over the nutrient pollution program on numeric regulation, or will you work with Florida and allow them to continue the lead that they have had previously?

Ms. STONER. And we are working with Florida to continue to help them to develop standards.

Senator SESSIONS. I think States and local communities do deserve respect. They know these waterways. And they have had some real great success in Tampa Bay and done some remarkably fine things. I think we will hear from them later.

Ms. STONER. We agree.

Senator SESSIONS. My time is up. Thank you, Mr. Chairman.

Senator CARDIN. Senator Inhofe?

Senator INHOFE. Thank you, Mr. Chairman.

Ms. Stoner, I have a very long question, but there is a question mark at the end. First of all, I am glad to have you before the Committee today. We have not had a chance to have a dialog about the direction the Office of Water has been taking.

I have expressed my concern over a number of issues, which you are aware, including the impending stormwater rule and the draft jurisdictional guidance document.

Of particular concern to me are the immense costs that are being passed to the States and local governments from these policies. Today I would like to focus on the idea of cooperative federalism versus coercive federalism.

I am extremely concerned that EPA keeps saying that they want to support the States' solutions, and give the States flexibility. I have a quote from you that I agree with wholeheartedly, it says States need room to innovate and response to local water quality needs. So a one size fits all solution to nitrogen and phosphorus pollution is neither desirable nor necessary. I agree with that.

In our next panel, we will hear from the Florida Agricultural Water Policy Director, Richard Budell. As well you know, EPA has taken over the process of setting numeric nutrient criteria for the State of Florida. This action has raised concern around the Country. To many States and stakeholders EPA appears to be in an aggressive pursuit of a number over and above the biological health of waters. Without the assurance of improved water quality, EPA is mandating that Florida municipal wastewater treatment facilities shoulder new compliance costs, estimated in the wide range, now, a range like this, there is something wrong, a wide range of $2.2 million and $6.7 billion annually, and that Florida's agricultural community incur an estimated $19.9 million, that is the EPA's number, to $1.6 million, which is Florida's number. So obviously, there is something wrong with this picture.

I would like to submit for the record several letters that have been written to the EPA, requesting that the EPA withdraw its rules, follow EPA's own nutrient framework and allow the State of Florida to take the lead in addressing the nutrient pollutants. So I would ask unanimous consent that be a part of the record.

Senator CARDIN. Without objection, those will be included.

[The referenced information follows:]

FLORIDA DEPARTMENT OF AGRICULTURE AND CONSUMER SERVICES
COMMISSIONER ADAM H. PUTNAM
THE CAPITOL

April 26, 2011

The Honorable Lisa Jackson
Administrator
U.S. Environmental Protection Agency
1200 Pennsylvania Avenue, N.W.
Washington, D.C. 20460

Dear Administrator Jackson:

I am writing to express my support of the petition submitted April 22, 2011, by the State of Florida Department of Environmental Protection (FLDEP), requesting the Environmental Protection Agency (EPA) to rescind the January 2009 EPA determination that numeric nutrient criteria are necessary in Florida, and return the rulemaking authority for nutrients to the state. As your office has stated, Florida has one of the most comprehensive surface water protection and restoration programs in the country and possesses the framework of accountability to address and enforce nutrient reductions in its own impaired waters.

As highlighted in the petition, the March 16, 2011, EPA memo from Nancy K. Stoner, titled *Working in Partnership with States to Address Phosphorus and Nitrogen Pollution through use of a Framework for State Nutrient Reductions,* detailed eight elements that provide the framework for states to effectively manage nitrogen and phosphorus pollution. Florida's commitment to these elements is demonstrated in its long history of statutory and rule based programs that foster interagency cooperation and watershed based programs to protect and restore our valuable surface water resources. Specifically, one of the elements describes the need for agricultural programs that target the implementation of the most effective practices to maximize environmental benefit.

Florida is recognized as having one of the most aggressive and comprehensive programs for implementing agricultural source controls in the nation. Florida has adopted rules for a variety of agricultural operations including citrus, container nurseries, beef cattle, forestry and row crops. Florida has also adopted rules for watersheds that are key components of Everglades and Lake Okeechobee restoration. As a result, over eight million acres of Florida agriculture are currently implementing approved best management practices.

In closing, I reiterate my support of the FLDEP petition and urge you to withdraw the January 2009 necessity determination, initiate repeal of 40 C. F. R Section 131.43 and discontinue further work to develop and finalize additional numeric criteria for Florida. If you have any questions of my office on this matter, please feel free to contact me.

Sincerely,

Adam H. Putnam
Commissioner of Agriculture

cc: Florida Congressional Delegation
Governor Rick Scott, State of Florida
Florida Senate President Mike Haridopolos
Florida House of Representatives Speaker Dean Cannon
Florida Senate Majority Leader Andy Gardiner
Florida Senate Minority Leader Nan Rich
Florida House Majority Leader Carlos Lopez-Cantera
Florida House Minority Leader Ron Saunders
Secretary Hershel T. Vinyard, Florida Department of Environmental Protection

Senator INHOFE. EPA's response to these requests, Florida can have its State control back only if it does what EPA thinks is good enough or as this June 2011 response says, adopts protective criteria sufficient to address the concerns underlying our determination in rule. It is, you can do it, as long as you come to our same conclusions.

In spite of the concerns raised with how EPA is trying to control nutrients in Florida, EPA is pushing other States to use the Florida model. Recently, EPA Region I rejected Maine's numeric nutrient criteria because they relied on a determination of whether a water body is biologically healthy using a weight of the evidence approach. This approach is recommended by EPA's science advisory board. Region I's response makes it clear that Maine's numeric criteria aren't good enough, and that they want them to adopt independently applicable limits, limits that apply regardless of the biological health of the water body, which is exactly what EPA has promulgated in Florida.

EPA's own nutrient framework memo is inconsistent. While stating "a one size fits all solution to nitrogen and phosphorus pollution is neither desirable nor necessary,' as I said before, it goes on to reinforce the inflexible position that States must adopt numeric nutrient criteria. I have a June 23, 2011 letter from 50 group expressing their concern that this policy is inflexible, scientifically indefensible and actually slowing progress toward reducing impairments associated with excess nutrients. I would like to ask that they be as part of this record also.

Senator CARDIN. Without objection.

[The referenced information follows:]

June 23, 2011

The Honorable Lisa Jackson
Administrator
U.S. Environmental Protection Agency
Ariel Rios Building
1200 Pennsylvania Avenue, N.W.
Mail Code: 1101A
Washington, D.C. 20460

Re: Numeric Nutrient Criteria

Dear Administrator Jackson,

The undersigned organizations are all partners and stakeholders committed to addressing nutrient loadings to our nation's waters. We would like to commend the U.S. Environmental Protection Agency (EPA) for acknowledging in the March 16, 2011 Memorandum from Nancy Stoner, Acting Assistant Administrator, Office of Water, to the EPA Regional Administrators, that states must take the lead in addressing nutrients and that: "states need room to innovate and respond to local water quality needs, so a one-size-fits-all solution to nitrogen and phosphorus pollution is neither desirable nor necessary."

We are concerned, however, that a March 1, 2011 letter from Acting Assistant Administrator Stoner responding on the issue of nutrients to a letter from the New England Interstate Water Pollution Control Commission, as well as the Office of Water's draft 2012 National Program Guidance, and language in the March 16, 2011 memorandum itself, undermine the important principle highlighted above. Rather than giving states room to innovate and respond to local water quality needs, the Agency appears to reinforce a more inflexible and counterproductive EPA position which has been held since 1998[1] and advanced more aggressively in recent years. This position is that states must adopt numeric nutrient criteria (NNC), in all water bodies, for both nitrogen and phosphorus which are "independently applicable" (i.e., apply regardless of actual observed and documented water body biology and in-stream impairment) even in the absence of a cause and effect relationship between nutrient levels and regardless of achievement of designated uses.

In the most public example of this dichotomy, EPA promulgated federal NNC for Florida lakes and flowing waters that are independently applicable. Thus, a water body is considered impaired even if it is otherwise healthy or if the biological impairment is related to a different factor (such as habitat alteration). Likewise, more restrictive numeric limits are then required in permits and dischargers will be required to install controls for one nutrient, such as nitrogen, when another nutrient, such as phosphorus, may be the most limiting.

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[1] National Strategy for Development of Regional Nutrient Criteria, 1998.

Without question, nitrogen and phosphorus pollution is a serious water quality problem in our nation. States are working hard to develop and implement a variety of approaches to control nutrients from both point and non-point sources. Some states have put considerable effort and resources into the process of developing NNC. However, given the difficulty of establishing scientifically defensible NNC under certain conditions, other states are:

- Focusing efforts on balancing biological, causal, and environmental response variables;
- Directly improving water quality by taking actions to reduce nutrient loadings;[2]
- Setting response criteria at levels to protect all designated uses;[3]
- Taking steps to control nutrients to protect downstream uses, such as monitoring to ensure uses are maintained, setting permit limits that ensure upstream discharges do not cause exceedances of downstream criteria, and applying antidegradation rules at upstream sites;
- Applying NNC only after verifying that nutrients are the cause of adverse water quality impacts in a water body;
- Adopting criteria for response variables, such as chlorophyll *a* or dissolved oxygen, instead of NNC;
- Using other indicators of adverse water quality impacts in a water body to direct reduction activities;
- Controlling both N and P, or only one, depending on the water body needs.

EPA's Science Advisory Board encourages these "weight of the evidence" approaches.[4] EPA's insistence that states must ultimately develop independently applicable NNC for all water bodies, even in the absence of a cause and effect relationship between the nutrient level and achievement of designated uses, is not scientifically defensible and is undermining innovative state approaches to reducing nutrient pollution. Continued controversy among EPA, states, and the regulated community over EPA's approach to nutrients is slowing progress towards reducing impairments associated with excess nutrients.

The undersigned organizations request that EPA take meaningful public steps to support innovative approaches for reducing nutrient loadings and, where a state believes NNC are appropriate, innovative approaches for developing scientifically defensible NNC.

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[2] Where progress is being made, the March 16 Memorandum appears to support a state focus on load reductions.

[3] The use of response criteria does not mean that no action will be taken before impairment occurs -- rather, it means that actions can be taken at the appropriate point so that designated uses are maintained; change will be detectable before impairment occurs.

[4] See *SAB Review of Empirical Approaches for Numeric Nutrient Criteria Derivation*, EPA-SAB-10-006 (April 27, 2010).

Sincerely,

NATIONAL AND MULTI-STATE ORGANIZATIONS

Association of State and Interstate Water Pollution Control Administrators
National Association of State Departments of Agriculture
National Association of Conservation Districts
National Association of Flood & Stormwater Management Agencies
National Water Resources Association
Western Coalition of Arid States
Agricultural Retailers Association
American Chemistry Council
American Farm Bureau Federation
American Forest & Paper Association
American Sugar Alliance
CropLife America
Edison Electric Institute
Federal Water Quality Coalition
National Alliance of Forest Owners
National Cattlemen's Beef Association
National Chicken Council
National Corn Growers Association
National Council of Farmer Cooperatives
National Pork Producers Council
Responsible Industry for a Sound Environment
The Fertilizer Institute
United Egg Producers
Utility Water Act Group

MUNICIPAL, CORPORATE & REGIONAL ENTITIES

Aurora Water, CO
City of Pueblo, CO
City of Yuma, AZ
Colorado River Water Conservation District
East Bay Dischargers Authority, CA
Georgia Association of Water Professionals
Littleton/Englewood Wastewater Treatment Plant, CO
San Juan Water Commission, NM
Virginia Association of Municipal Wastewater Agencies
Wyoming Association of Conservation Districts
Alcoa
Florida Pulp & Paper Association
GROWMARK

PotashCorp
Rayonier Corporation
Delaware Maryland Agribusiness Association
Tennessee Paper Council
US Steel
Virginia Agribusiness Council
Virginia Grain Producers Association
Virginia Poultry Federation
Wyoming Ag-Business Association
Wyoming Crop Improvement Association
Wyoming Farm Bureau Federation
Wyoming Stock Growers Association
Wyoming Wheat Growers Association

cc: Nancy Stoner, Acting Assistant Administrator, Office of Water

Senator INHOFE. So when EPA had the opportunity to follow through on its own stated desire to give States room to innovate and respond to local water quality needs, they have instead opted for their own answer to the problem. It is no wonder that States no longer feel the EPA is cooperating with them in trying to clean up waters, but instead is coercively pushing them to adopt a costly, heavy-handed EPA solution.

So finally, Ms. Stoner, on August 17th of 2011, several of my colleagues and I sent you a letter voicing our concerns about the very wide and potentially expensive net that EPA cast in its advanced notice for proposed rulemaking for stormwater. Int hat letter, we asked 20 questions. There are several of these questions that were not answered, so my question to you would be, No. 1, when exactly are you planning to send your required report to Congress? And No. 2, will that report on the stormwater rule economic analysis contain jobs impact numbers?

Ms. STONER. Thank you, Senator.

I would like to respond to a number of points that you made. First of all, in terms of State water quality standards, the way the Clean Water Act works is that States are the principal one to determine what the water quality standards are, based on the uses of the waters, to ensure that the waters are usable for fishing, swimming, drinking water, whatever it is that those are used for. That is a science-based decision.

But then when the implementation of those standards occur, there is lots of flexibility in determining how to implement them so as to make sure that they are cost-effective.

You asked about the costs.

Senator INHOFE. And you are saying that then would be at the option of the States. I would hope that the next panel is in here and is listening, because I am going to ask them the same questions, similar questions in terms of how they are being treated in this respect.

Ms. STONER. You asked about the costs in Florida. And there are very widely differing estimates. EPA's estimates are based on assuming that the flexibility that exists in the Clean Water Act and the regulations will be employed in implementation of the water quality standards in Florida. And that is why our number is lower than numbers that others give, based on assuming that the flexibilities that are in the law will not be used.

We have asked the National Academy of Sciences to take a look at that, to help us determine what the right costs are.

You also asked about the standard for approval of those standards. So it is not based on EPA opinion, it is actually based on the Clean Water Act standards. And that is what Congress has given EPA a role in approving State water quality standards. And so that would be the test that we would use in determining whether or not Florida's standards can be approved.

We do hope that they set standards that are approvable, and we are working very closely with them to share data, to share models, technical assistance, meeting with them on a regular basis to ensure that they submit standards that will be approvable. We hope that is the case.

Senator INHOFE. Let me interrupt at this point, because we are way over my time. It is unfair to the rest of them. But the questions you said I asked I didn't ask. I asked the questions, when exactly are you planning to send the required report to Congress and will that report have the economic analysis containing jobs impact statements.

So those are the two questions. You can answer them for the record if you would like.

Ms. STONER. Yes, sir. On the first question, we will be following the Clean Water Act, which requires the report to Congress under Section 402(p)(5) to be submitted before a decision is made to take further action under 402(p)(6). That is what the Clean Water Act requires, and we will be submitting that report before we go out with a proposal to propose any regulations under 402(p)(6) under the stormwater—I am sorry, was there another question?

Senator INHOFE. No, that is all right, because I had suggested you answer those for the record, because we are using too much time here. So you have those questions, we would like those answers. Those two questions.

Ms. STONER. Thank you, Senator.

Senator CARDIN. Senator Whitehouse?

Senator WHITEHOUSE. Thank you, Chairman.

Ms. Stoner, there is a technique, I would guess, or a series of techniques that are described as green infrastructure, although since it is water-based, maybe blue infrastructure would be a better term, that are designed to mimic natural processes of evaporation and filtration and have proven effective in reducing nutrient pollution. I am wondering, Senator Udall and I have introduced legislation called the Green Infrastructure for Clean Water Act of 2011, which would add green infrastructure as an option in the permitting process. I am wondering what you feel the authorities are that you have right now with respect to green infrastructure and whether you consider that to be a promising means of trying to protect our waterways from the nutrient pollution that we are seeing so often.

Ms. STONER. Yes, Senator.

First of all, the green infrastructure usually is referring to the vegetation associated with it, although it doesn't always involve vegetation. But it is also called low impact development sometimes, and other types of names. And it is a very promising technique, not viewed only that way by EPA, but by State and local communities, by conservationists, by fishermen, by business leaders. It is actually booming across the Country, because people are very interested in it because of the multiple benefits that it provides. It helps revitalize cities, helps not only cleanup the waterways and restore water supplies, but also address urban heat island effect, air quality, all kinds of things.

Senator WHITEHOUSE. Can it result in cost savings compared to mechanical and chemical methods of treatment?

Ms. STONER. Often it can. It is not universal that it always does, but often it can, particularly when those benefits are considered. And it also helps drive investment in cleaned up waterways and neighborhoods that have implemented green infrastructure techniques, so it can bring in revenue as well. So it is very popular, we have lots of demands for assistance and help all across the United States and we can't meet them all. But we do have authority, which was your question, to work with communities now under existing, the State revolving funds, the 319 program and other funds that we have now. And we are doing the best we can to meet those requests for assistance.

Senator WHITEHOUSE. One other question. Rhode Island has done a very good job of addressing the point source for nutrient, the point sources for nutrient, that have contaminated Narragansett Bay and Mount Hope Bay for a long time. And there really isn't, I don't think, a whole lot left to be done from a point source perspective. We have huge CSO investment to be able to filter the water from storms that wash everything into combined sewer-storm systems. We have worked with some of the major polluters, the Bay Commission, Narragansett Bay Commission has been very effective in dealing with that.

We are now at the point where non-point source, general runoff, and what comes in from other States, down the Blackstone River, down the Taunton River, through the Paucantuck Watershed from Connecticut, is having a fairly pronounced effect on us. I would love to have you say a few words on how the framework for State nutrient reduction process that we have been talking about can utilize a watershed approach in those instances where you have multi-State participation in the watershed, and perhaps the incentives of the polluting States are a little bit diminished in terms of cleanup, because the effects aren't felt in their waters, they are felt in our waters.

Ms. STONER. Yes. One of the provisions that is relevant to this is the provision in the regulations that actually requires standards, and there is also one for permitting in the upstream States, to consider the downstream impacts. So because water pollution does not know State bounds, and because we want to ensure that everyone in the Country can go anywhere in the Country and know that it is safe to drink the water and swim in the waterways and so forth, the Clean Water Act was set up with those balances, with local water quality standards set to protect designated uses, but also to protect those of downstream States, as you are discussing there.

Senator WHITEHOUSE. Thank you, Mr. Chairman.

Senator CARDIN. Senator Boozman?

Senator BOOZMAN. Thank you, Mr. Chairman.

In regard to the numeric standards, Ms. Stoner, you said that a lot of States wanted to implement and go that direction, that they were easy. I think the reality is that a lot of States don't want to go that direction. Because they feel like they can do a better job of actually looking, I think as Mr. Werkheiser described, all of the different things that affect, canopies of trees, you mentioned the other things that can play into this. Should they have the ability to decide for themselves?

Ms. STONER. If I meant to suggest that it is easy to set numeric nutrient standards, that is not what I meant. It is actually a scientific inquiry that can be complex. But it is easier to implement them. So I just wanted to say that.

And I did want to say that we are, as I mentioned earlier, we have a workshop tomorrow on the use of biological assessment in State water programs.

Senator BOOZMAN. Should the States have the right to use the narrative approach, which also can work, if they choose to do that?

Ms. STONER. We are working with States to explore the flexibilities that exist in the Clean Water Act.

Senator BOOZMAN. I understand, but if they decide that they want to use the narrative approach, and use the factors that Mr. Werkheiser described, which at some point I would like to visit about whether or not we are actually doing that as we decide numeric standards, but should they have the right under the Clean Water Act, if they wish to do that, should they have the right to do that?

Ms. STONER. Where there——

Senator BOOZMAN. You talk a lot about collaborating. It seems like the collaboration only works as long as the State agrees with what you say.

Ms. STONER. No, sir, the collaboration works when there is a scientific basis and a legal basis for the standard. And as long as those criteria are met, then it is approvable and we approve it.

Senator BOOZMAN. So you agree then that the States should have the right to not use the numeric standard, but the other?

Ms. STONER. We are working on approaches now that would be approvable approaches that could use narratives for biological assessments.

Senator BOOZMAN. OK. You talk a lot about collaboration with the States. I guess my problem is, if that is true, again, it seems like collaboration exists as long as the State does what you wish it to do. The reality is that it seems like so many people are very upset with the standards that you have come out with in regard to the State and the local stakeholders. Can you give us some examples of specific things that you are trying to do to help with the collaboration?

Ms. STONER. You bet. So we are working directly with the State of Ohio on a weight of evidence approach right now. We approved standards in the State of Wisconsin, phosphorus standards there. We are working in Montana, we are working with the State there on putting together the record that would be necessary to support the variances that were passed by the State legislature there. We are working in multiple States, Colorado is another one, on a variety of approaches to set approvable State standards that would help reduce nutrient pollution.

Senator BOOZMAN. Mr. Werkheiser, in your opinion in regard to the method that is used as far as setting a numeric standard or using another method, of actually looking at the things that you talked about, is it reasonable if a State comes up with a plan in that regard to allow them to do that as opposed to just saying, you are at .1 or .05 or whatever?

Mr. WERKHEISER. I can answer from a scientific standpoint, not a regulatory standpoint. From a scientific standpoint, we work with both setting numeric standards and other standards, taking into account all those variables that go into an effective nutrient reduction strategy. So regardless of how the standard is set, we work on the scientific basis on the whole range of factors that are relevant.

Senator BOOZMAN. So it is reasonable, then, for a State to go a different direction, and possibly do a better job, as opposed to the one size fits all?

Mr. WERKHEISER. From a scientific standpoint, as long as you take into take into account all those variables, I think that is absolutely right.

Senator BOOZMAN. So it would be reasonable that in fact you can actually do a better job if you took those variables into account?

Mr. WERKHEISER. From our standpoint, regardless of what you use, and the important thing is taking the variables, whether it is a numeric value or a different standard.

Senator BOOZMAN. Thank you. Thank you, Mr. Chairman.

Senator CARDIN. Thank you.

Let me if I might introduce into the hearing record a report released last week by the USDA's Economic Research Service. The report on nitrogen in agricultural systems noted that the introduction of large amounts of nitrogen into the environment has a number of undesirable impacts on water, terrestrial and atmospheric Resources. The report also notes that two-thirds of U.S. cropland is not meeting the three criteria for good nutrient Management.

Without objection, that will be included in the Committee record.

[The referenced information follows:]

United States
Department of
Agriculture

USDA

Economic
Research
Service

Nitrogen in Agricultural Systems: Implications for Conservation Policy

Economic
Research
Report
Number 127

Marc Ribaudo, Jorge Delgado, LeRoy Hansen, Michael Livingston,
Roberto Mosheim, and James Williamson

September 2011

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Photo courtesy of USDA, Natural Resources Conservation Service.

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of Agriculture

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Number 127

September 2011

A Report from the Economic Research Service

www.ers.usda.gov

Nitrogen in Agricultural Systems: Implications for Conservation Policy

Marc Ribaudo, mribaudo@ers.usda.gov
Jorge Delgado
LeRoy Hansen
Michael Livingston
Roberto Mosheim
James Williamson

Abstract

Nitrogen is an important agricultural input that is critical for crop production. However, the introduction of large amounts of nitrogen into the environment has a number of undesirable impacts on water, terrestrial, and atmospheric resources. This report explores the use of nitrogen in U.S. agriculture and assesses changes in nutrient management by farmers that may improve nitrogen use efficiency. It also reviews a number of policy approaches for improving nitrogen management and identifies issues affecting their potential performance. Findings reveal that about two-thirds of U.S. cropland is not meeting three criteria for good nitrogen management. Several policy approaches, including financial incentives, nitrogen management as a condition of farm program eligibility, and regulation, could induce farmers to improve their nitrogen management and reduce nitrogen losses to the environment.

Keywords

Reactive nitrogen, nitrogen management, fertilizer, water quality, greenhouse gas, economic incentives, conservation policy, regulation

Acknowledgments

This report benefited from the insightful comments provided by Keith Fuglie, Marca Weinberg, and Mary Bohman of USDA's Economic Research Service, Ralph Heimlich of Agricultural Conservation Economics, Roberta Parry of the U.S. Environmental Protection Agency, Jerry Hatfield of USDA's Agricultural Research Service, USDA's Natural Resources Conservation Service and an anonymous reviewer. Thanks also to John Weber for excellent editorial assistance and to Curtia Taylor for the design and layout.

Contents

Summary

What Is the Issue?

Nitrogen is an agricultural input that is critical for crop production. Human-induced production and release of reactive nitrogen has greatly affected the Earth's natural balance of nitrogen, contributing to changes in ecosystems, both beneficial and harmful, including increased agricultural productivity in nitrogen-limited areas, ozone-induced injury to crops and forests, over-enrichment of aquatic ecosystems, biodiversity losses, visibility-impairing haze, and global climate change. Incentives for encouraging farmers to adopt improved nitrogen management can take many forms, from purely voluntary to regulatory. Designing a cost-effective policy requires that factors influencing fertilizer use be fully understood. Also, an understanding of how farmers are likely to respond to different incentives may help policymakers assess potential environmental tradeoffs driven by nitrogen's ability to change forms and cycle through different environmental media.

What Did the Study Find?

- Emission of reactive nitrogen to the environment can be reduced by matching nitrogen applications more closely with the needs of growing crops. This can be achieved by adopting three "best management practices" (BMPs):
    - *Rate*: Applying an amount of nitrogen at a rate that accounts for all other sources of nitrogen, carryover from previous crops, irrigation water, and atmospheric deposits.
    - *Timing:* Applying nitrogen as close to the time that the crop needs it as is practical (as opposed to the season before the crop is planted).
    - *Method:* Injecting or incorporating the nutrients into the soil to reduce runoff and losses to the atmosphere.
- Among all U.S. field crops planted in 2006 that received nitrogen fertilizers, 35 percent are estimated to have met all three of the nutrient BMPs. For the remaining cropland, improvements in management are needed to increase nitrogen use efficiency (i.e., reduce the amount of nitrogen available for loss to the environment).
- Corn is the most intensive user of nitrogen fertilizer, on a per acre basis and in total use. Fertilizer applied to corn is least likely to be applied in accordance with all three BMPs.
- Incentives for improving nitrogen use efficiency by adopting the rate, timing, and method BMPs can come from policy or market forces:
    - Government programs that provide financial assistance for adopting BMPs can be effective if they encourage the participation of farmers with land most in need of improvement and if the farmers choose the most cost-effective practices. Data suggest that the amount of cropland needing improvement would require a substantial increase in the current Federal budget devoted to nutrient management practices.

- Including nitrogen management in compliance provisions for receiving Federal farm payments could encourage farmers to adopt more effective management practices. In 2005, producers of U.S. corn received Government payments that were much higher than the cost of improving nitrogen management. The strength of this incentive, however, has declined in recent years because of increases in crop prices and a decline in direct commodity payments.

- Emissions markets, such as water quality trading and greenhouse gas cap-and-trade, could provide financial incentives to farmers to adopt improved nitrogen management and produce nitrogen credits that can be sold in these markets. The effectiveness of such markets would depend on market design, including rules defining who can participate and what needs to be done to produce credits.

- Onfield improvements to nitrogen use efficiency could be supplemented with off-field practices, such as wetlands restoration and vegetative filter strips that can filter and trap reactive nitrogen that leaves the field through surface runoff and groundwater flow. Of the two practices, restored wetlands can be more cost effective at removing nitrogen and provide additional environmental benefits, but they are limited to areas with suitable soils and hydrology. Vegetative filters can be employed more widely across the landscape but are not effective when existing tile drains bypass the filters.

- Policies for increasing nitrogen use efficiency should recognize the potential environmental tradeoffs when addressing particular issues related to reactive nitrogen. Focusing strictly on one issue, such as nitrate leaching, could lead to increased emissions of other nitrogen compounds, such as nitrous oxide, even when total reactive nitrogen emissions are reduced.

How Was the Study Conducted?

ERS researchers used an extensive literature review, modeling, and data from USDA's Agricultural Resource Management Survey (ARMS) of major field crops. ARMS data provided information on nitrogen use, defined by the rate, method, and timing application criteria. This, in turn, helped researchers determine the types of management improvements needed the most.

The following market forces and policy instruments were evaluated to measure their influence on nitrogen management: nitrogen fertilizer taxes, Federal financial assistance offered to farmers to adopt practices that improve nitrogen use efficiency or filter and trap nitrogen runoff, emissions markets such as water quality trading and greenhouse gas cap-and-trade, compliance with nitrogen BMPs as a condition for receiving farm program benefits, and regulation.

Because reactive nitrogen is mobile and able to transform into different compounds, researchers used a field-level nitrogen loss simulator developed by USDA's Agricultural Research Service to track how improving nitrogen use efficiency by meeting all three BMPs affects emissions of different reactive nitrogen compounds. These interactions were taken into account when evaluating alternative policy options.

Glossary

ARMS – Agricultural Resource Management Survey

BMP – Best management practice

CEAP – Conservation Effects Assessment Program

EQIP – Environmental Quality Incentives Program

NUE – Nitrogen use efficiency

N – Nitrogen

N_2 – Gaseous nitrogen

NO_3 – Nitrate

NO_x – Nitrogen oxides

N_2O – Nitrous oxide

NH_3 – Ammonia

Nr – Reactive nitrogen

NRCS – Natural Resources Conservation Service (USDA)

VFS – Vegetative filter strip

Chapter 1

Introduction

Most of the cropping systems in the world are naturally deficient in nitrogen, making nitrogen inputs necessary to produce the crop yields needed to support human populations. Gaseous nitrogen (N_2) is abundant in the atmosphere, but it cannot be used by living organisms unless it is first converted into useable forms. Leguminous plants and soil microorganisms contribute significant amounts of nitrogen used by crops, but yields necessary to support growing populations need more nitrogen than can be provided by natural means.

The Haber-Bosch process converts "unreactive" gaseous nitrogen from the atmosphere into a biologically useable "reactive" form. The development of the process in the early 1900s led to the massive production of relatively inexpensive nitrogen fertilizer that boosted crop yields (Follett et al., 2010). The increasing use of reactive nitrogen in agriculture also increased the potential for nitrogen to be lost to the environment as ammonia (NH_3), ammonium (NH_4), nitrogen oxides (NO_x), nitrous oxide (N_2O), and nitrate (NO_3); these compounds are all reactive forms of nitrogen (Galloway et al., 2003). Excessive amounts of reactive nitrogen inputs can lead to imbalances in the natural movement of nitrogen among atmospheric, terrestrial, and aquatic nitrogen pools, leading to disruptions in ecosystem function and the supply of valuable ecosystem services.

Reactive nitrogen directly affects species composition, diversity, dynamics, and the functioning of terrestrial, freshwater, and marine ecosystems (Matson et al., 1997; Vitousek et al., 1997). Human-induced increases in reactive nitrogen emissions to the environment may contribute to the following harmful changes to ecosystems:

- Ozone-induced injury to crop, forest, and natural ecosystems
- Acidification and eutrophication (nutrient enrichment) effects on forests, soils, and freshwater aquatic ecosystems
- Eutrophication and hypoxia (oxygen depletion) in coastal and lake ecosystems
- Harmful algae blooms
- Biodiversity losses in terrestrial and aquatic ecosystems
- Regional haze
- Depletion of stratospheric ozone
- Global climate change
- Nitrate contamination of drinking water aquifers

A variety of steps can be taken to reduce the relatively large share of nitrogen that is lost from agricultural systems. Improved management of nitrogen fertilizers, animal manure, and other agricultural inputs can improve overall nitrogen use efficiency (NUE) and reduce the loss of reactive nitrogen to the environment while maintaining crop yields.

Incentives for encouraging farmers to adopt improved nitrogen management can take many forms, from purely voluntary to regulatory. Designing a cost-effective policy requires that factors influencing fertilizer use be fully understood. Also, an understanding of how farmers are likely to respond to different incentives may help policymakers assess potential environmental tradeoffs driven by nitrogen's ability to change forms and cycle through different environmental media.

This report takes a broad view of several questions related to nitrogen management: (1) Why is nitrogen management so important? (2) How many acres of cropland are not using nitrogen best management practices (BMP)? and (3) What are the strengths and weaknesses of alternative policy approaches for improving nitrogen management on those acres?

Ideally, alternative policies would be assessed on the basis of the cost of achieving a particular level of NUE across U.S. crop production. However, physio-economic models that would allow for this type of assessment are not available on a national scale. Instead, this analysis uses survey data to help identify the number of acres of cropland that would benefit from improved management and to assess the characteristics of each alternative policy approach. Policy approaches are assessed in terms of factors consistent with cost effectiveness, including flexibility, ability to target, crop acres covered, and implementation costs. These factors are assessed through original research and an extensive review of the literature.

Chapter 2

Environmental Implications of Nitrogen and Goals for Agricultural Management

Agriculture is the predominant source of reactive nitrogen emissions into the environment. In the United States, agriculture contributes 73 percent of nitrous oxide emissions (EPA, 2010a), 84 percent of ammonia emissions (EPA, 2010a), and 54 percent of nitrate emissions (Smith et al., 1997). Most losses from cropland are attributable to runoff, ammonia volatilization, nitrification and denitrification, and nitrate leaching (see box, "Pathways for Nitrogen Losses").

Nitrogen's impacts on water resources (Dubrovsksy et al., 2010; Bricker et al., 2007; Rabalais et al., 2002a, b), atmosphere (Cowling et al., 2002; Follett et al., 2010), and terrestrial resources (Galloway et al., 2008) are extensive. Estimates of the economic value of these damages are lacking. Crutchfield et

Pathways for Nitrogen Losses

Soil erosion - Nitrogen can be lost from the soil surface when attached to soil particles that are carried off the field by wind or water. Although wind and water erosion can be observed across all regions, wind erosion is more prevalent in dry regions and water erosion in humid regions. Overall, little nitrogen is lost through erosion when basic conservation practices are in place (Iowa Soybean Association, 2008b).

Runoff - Surface runoff of dissolved nitrogen (generally in the form of nitrate) is only a concern when fertilizer and or manure are applied on the surface and rain moves the nitrogen before it enters the soil (Legg and Meisinger, 1982; Iowa Soybean Association, 2008b).

Ammonia volatilization - Significant amounts of nitrogen can be lost to the atmosphere as ammonia (NH_3) if animal manure or urea is surface applied and not immediately incorporated into the soil (Hutchinson et al., 1982; Fox et al., 1996; Freney et al., 1981; Sharpe and Harper, 1995; Peoples et al., 1995). Additionally, warm weather conditions can accelerate the conversion of manure and other susceptible inorganic nitrogen fertilizers to ammonia gas.

Denitrification and nitrification - When oxygen levels in the soil are low, some microorganisms known as denitrifiers will convert NO_3 to nitrogen (N_2) and nitrous oxide (N_2O), both of which are gases lost to the atmosphere (Mosier and Klemedtsson, 1994). Nitrogen gas is not an environmental issue, but N_2O is a powerful greenhouse gas. Denitrification usually occurs when nitrate is present in the soil, soil moisture is high or there is standing water, and soils are warm. NO_x and N_2O gases can also be produced through a process called nitrification.

Leaching - Leaching occurs when there is sufficient rain and/or irrigation to move easily dissolvable nitrate through the soil profile (Randall et al., 2008). The nitrate eventually ends up in underground aquifers or in surface water via tile drains and groundwater flow. Tile drains may be a chief passageway by which nitrogen moves from crop soils to surface water (Turner and Rabalais, 2003; Randall et al., 2008; Randall et al., 2010).

al. (1995) estimate that consumers in four U.S. rural areas would be willing to pay between $73 million and $780 million per year (in 1995 dollars) for reduced chemical concentrations (including nitrate) in groundwater tapped by private wells. Dodds et al. (2009) estimate that consumers spend over $800 million each year on bottled water due to nutrient-related taste and odor problems.

Using data from water treatment plants, ERS estimates the cost of removing nitrate from U.S. drinking water supplies is over $4.8 billion per year (see app. 1). Based on the contribution of nitrate loadings from agriculture (Smith et al., 1997), agriculture's share of these costs is estimated at about $1.7 billion per year. Most costs are borne by the large utilities, due to the volume of water treated. ERS findings indicate that reducing nitrate concentrations in source waters by 1 percent would reduce water treatment costs in the United States by over $120 million per year.

Managing Nitrogen for Agriculture and the Environment

USDA's Natural Resources Conservation Service (NRCS) defines nutrient management as managing the amount, source, placement, form, and timing of the application of plant nutrients to the soil (USDA, NRCS, 2006). Optimizing nitrogen management both economically and environmentally requires farmers to perform a juggling act: Applying too much nitrogen cuts into financial returns and increases the likelihood of nitrogen escaping into the environment; applying too little increases the risk of reduced yields and lost income.

Crop production is characterized by uncertain and stochastic, or random, weather and soil conditions that affect crop yields and nitrogen loss. To maintain viable operations, farmers may manage temporal variability in weather and soil nitrogen by overapplying nitrogen to protect against downside risk (i.e., use an "insurance" nitrogen application rate) (Sheriff, 2005; Babcock, 1992; Babcock and Blackmer, 1992). Additionally, farmers may take a "safety net" approach to maximize economic returns by setting an optimistic yield goal for a given field based on an optimum weather year to ensure that the needed amount of nitrogen for maximum yields is available (Schepers et al., 1986; Bock and Hergert, 1991). Thus, during the years in which weather is not optimal for maximizing yields, nitrogen will be overapplied from an agronomic standpoint. Almost by definition, optimal conditions are infrequent, so farmers overfertilize crops in most years.

The following hypothetical example helps illustrate the reasoning behind a farmer's decision to apply a certain amount of fertilizer. Assume that a farmer applies 179 pounds of nitrogen (N) per acre to his or her cornfield. Under ideal conditions, the farmer might produce 170 bushels of corn per acre. In most years, however, conditions are not ideal and production averages 148 bushels per acre. This yield requires only 165 pounds of N per acre, but at this level, the farmer will miss out on an extra 22 bushels in the event of ideal weather conditions. Assuming a fertilizer price of $0.50 per pound of N, the extra N applied in an average year costs $7 per acre. Assuming a corn price of $4.50 per bushel, the benefit from having enough nitrogen available to take advantage of optimal conditions would be $99 per acre. In most years, however, the extra fertilizer is not used by the crop and is available to leave the field and affect environmental quality.

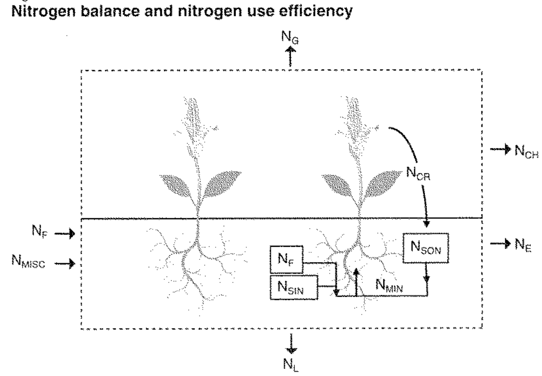
Definitions of Nitrogen Use Efficiency

Researchers calculate nitrogen use efficiency to assess the effectiveness of nitrogen management. The NUE of a cropping system is the proportion of all nitrogen inputs that are removed in harvested crop biomass, contained in recycled crop residues, and incorporated in soil organic and inorganic nitrogen pools (Cassman et al., 2002) (fig. 2.1). Nitrogen not recovered in these nitrogen sinks is lost to the environment. Increases in NUE reduce the share of nitrogen left in the soil and available for loss to water or the atmosphere. Increased NUE is treated as a goal of environmental policy throughout this report.

Recommended Input Rate and Nitrogen Credits

The nitrogen application rate has a major effect on NUE (Bock and Hergert, 1991; Meisinger et al., 2008; Freney et al., 1995; Power et al., 2001). Nitrogen losses have been shown to increase rapidly when N inputs exceed assimilation capacity (Vanotti and Bundy, 1994; Schlegel et al., 1996; Dobermann et al., 2006; Bock and Hergert, 1991). Reducing application rates reduces the losses of all forms of reactive nitrogen.

Figure 2.1
Nitrogen balance and nitrogen use efficiency



Nitrogen balance consists of N inputs of fertilizer and manure/legume N (N_F) and miscellaneous atmospheric deposition (N_{MISC}); outputs of crop harvested N (N_{CH}), N leaching (N_L), erosion (N_E), and gaseous losses (N_G); and internal N pools of crop residue N (N_{CR}), soil organic N (N_{SON}), soil inorganic N (N_{SIN}), and net N mineralization (N_{MIN}). Nitrogen use efficiency is the proportion of all N inputs (N_F and N_{MISC}) that are removed in harvested crop biomass (NCH), contained in recycled crop residues (N_{CR}), and incorporated into soil organic matter (N_{SON}) and inorganic N (N_{SIN}) pools. The remainder is what is lost to the atmosphere through gaseous emissions (N_G), leaching (N_L), and erosion (N_E). The goal of nitrogen management is to reduce these losses through reductions in fertilizer inputs and through soil, water, fertilizer, and crop management that affects the cycling of nitrogen in the soil.

Source: USDA, Economic Research Service using data from Meisinger et al., 2008.

The effectiveness of nitrogen management may be raised by accounting for all nitrogen sources when determining a nitrogen fertilizer application rate. Depending on the region, such sources may include inorganic nitrogen levels in the root zone, soil organic content, previous crop (e.g., leguminous crop), manure applications, irrigation water, and atmospheric deposition (Cassman et al., 2002; Meisinger et al., 2008; Iowa Soybean Association, 2008a).

Method/Placement

The goal of appropriate method and placement of fertilizer is to provide nutrients to plants for rapid uptake and to reduce the potential for losses to the environment. Studies have shown that NUE can be doubled under some conditions by placing fertilizers in the soil rather than "broadcasting" them on the surface (Malhi and Nyborg, 1991; Power et al., 2001). Liquid or gaseous forms of nitrogen can be injected directly into the soil with specialized equipment that is consistent with low-till systems. Solid forms can be broadcast on the surface and immediately incorporated into the soil with tillage equipment. Such placement reduces the risks of losses to the atmosphere and through surface runoff. The method of application can also reduce losses of nitrogen stemming from ammonia volatization (Meisinger and Randall, 1991; Peoples et al., 1995; Fox et al., 1996; Freney et al., 1981).

The impact of fertilizer placement on nitrous oxide emissions is less certain. Liu et al. (2006) found that injection of liquid urea ammonium nitrate at deeper levels resulted in 40-70 percent lower N_2O emissions than the rate associated with shallow injection or surface application. Some studies, however, have reported that incorporation into the soil increases N_2O emissions (Flessa and Beese, 2000; Wulf et al., 2002; Drury, 2006). Injection or incorporation could also increase nitrate leaching, especially where soils are coarse textured (Abt Associates, 2000).

Timing

The research on improving NUE in crop production emphasizes the need for greater synchronization between crop nitrogen demand and the supply of nitrogen from all sources throughout the growing season (Doerge et al., 1991; Cassman et al., 2002; Meisinger and Delgado, 2002). Balancing supply and demand implies maintaining low levels of inorganic nitrogen in the soil when there is little plant growth and providing sufficient inorganic nitrogen fertilizer during periods of rapid plant growth (Doerge et al., 1991; Alva et al., 2005). For example, the corn plant's need for nitrogen is not very high until about 4 weeks after it emerges from the ground, which typically falls in June through July in the major corn-producing States (Baker, 2001). Ideally, to ensure that growing crops have adequate N and to minimize losses from the soil, a farmer could split nitrogen applications or "spoon feed" nitrogen when using center-pivot sprinkler irrigation systems from June through July-August, using information from soil tests and/or advanced remote sensing techniques (Bausch and Delgado, 2003). Though splitting nitrogen applications is seen as an effective way to increase NUE and reduce nitrogen losses to the environment, several factors must first be considered: workload, seasonal fertilizer price differences, the risk associated with not being able to apply at the right time, application costs, the possibility of compacting the soil, and possible damage to growing crops (Doerge et al. 1991; Westermann and Kleinkopf, 1985; Westermann et al., 1988; Alva et al., 2005; Delgado and Bausch, 2005).

Form

NUE is also influenced by the form of nitrogen fertilizer (Raun and Schepers, 2008; Freney et al., 1995). Some of the more widely used nitrogen fertilizer forms include anhydrous ammonia (gas), urea (solid), UAN (liquid), and manure (solid). These forms vary in how quickly they can be transformed into nitrate, which is what crops actually use. The closer in time the fertilizer is applied to when the crop needs it, the faster it needs to be transformed into nitrate. A mismatch of fertilizer form with appropriate timing can lead to large environmental losses and poor yields.

Manure Effects

Manure is an important source of N, but it poses challenging management problems (Eghball et al., 2002; Kirchmann and Bergstrom, 2001; Davis et al., 2002). The nitrogen content of manure depends on the animal type and the method of manure storage (Davis et al., 2002; Eghball et al., 2002), and nitrogen content may be inconsistent from batch to batch (Davis et al., 2002). Manure is more difficult to handle than inorganic nitrogen fertilizers, and, if in solid form, is difficult to apply uniformly. Most of the nitrogen content of manure is in the organic form and has to be mineralized before crops can use it. Since the transformation process depends on manure type, soil, and weather conditions, it is more difficult to control soil nitrate levels relative to crop needs when manure is applied than when other forms are applied (Eghball et al., 2002; Power et al., 2001). Consequently, controlling environmental losses from manured fields is more difficult than from fields using commercial fertilizer.

Off-Site Practices That Capture Nitrogen

Off-field conservation measures can be used in conjunction with onfield nitrogen management to either capture reactive nitrogen in biomass or convert it to inert N_2 through denitrification. Examples of off-site practices include vegetative buffers or filters and restored and constructed wetlands (Hefting et al., 2003; Jacobs and Gilliam, 1985; Lowrance et al., 1984). Buffers and wetlands reduce nitrogen loads to water through plant uptake, microbial immobilization and denitrification, soil storage, and groundwater mixing (Pionke and Lowrance, 1991; Lowrance et al., 1997; Hey et al., 2005; Mayer et al., 2005).

Buffers can remove nitrogen from both surface flow and groundwater (Mayer et al., 2005; Angier et al., 2001; Randall et al., 2008; Mitsch and Day, 2006). The effectiveness of vegetative buffers depends on the size of the buffer, the density of vegetation, and hydrologic conditions within the buffer zone (Dosskey et al., 2005; 2007). Based on a wide range of studies, Mayer et al. (2005) estimate that buffers can remove about 74 percent of the nitrogen passing through the buffer root zone. However, in many areas of the country where tile drains are used to control the water table, especially in the Corn Belt, subsurface flows pass below the root zone and are not filtered by vegetative buffers.

Restored wetlands have been shown to be effective at reducing the transfer of nitrogen from agricultural land to water bodies (Jansson et al., 1994) and have been proposed as a technique to remove reactive nitrogen from the environment (Hey et al., 2005; Mitsch and Day, 2006). Wetland vegetation uptakes nitrogen, and wet soils enhance denitrification. The effectiveness of wetlands as a filter of reactive nitrogen depends on their size, seasonal weather conditions, and hydrologic characteristics. Wetlands also provide a host of other ecosystem services that are valued by society, such as wildlife habitat and carbon sequestration.

Chapter 3

State of Nitrogen Management on Cropland

Nitrogen Management on U.S. Cropland

Data on the nutrient management practices of U.S. producers of barley, corn, cotton, oats, peanuts, sorghum, soybeans, and wheat (table 3.1) are derived from USDA's Agricultural Resource Management Survey (ARMS) (see box, "Agricultural Resource Management Survey"). The basic practices for improving NUE are agronomic application rate, appropriate timing of applications, and proper placement (USDA, NRCS, 2006). For the purposes of this analysis, these practices are defined as follows:

- ***Rate.*** Applying no more nitrogen (commercial and manure) than 40 percent more than that removed with the crop at harvest, based on the stated yield goal, including any carryover from the previous crop. This approach is consistent with a more traditional approach for estimating N rate recommendations (Millar et al., 2010) and is also the criterion used by NRCS in its assessment of conservation practices in the Upper Mississippi Basin (USDA, NRCS, 2010). Crop uptake coefficients are from NRCS (Lander et al., 1998, table 3.1). This agronomic rate accounts for unavoidable environmental losses that prevent some of the nitrogen that is applied from actually reaching crops.

Table 3.1
Crops, ARMS Phase II reference years, States surveyed, commodities, and nitrogen uptake per unit of crop yield

Crop	Reference year	States surveyed	Commodity	Lbs N per unit	Unit
Barley	2003	CA, ID, MN, MT, ND, PA, SD, UT, WA, WI, WY	grain	0.9	bushel
Corn	2005	CO, GA, IL, IN, IA, KS, KY, MI, MN, MO, NE, NY, NC, ND, OH, PA, SD, TX, WI	grain	0.8	bushel
			silage	7.09	ton
Cotton	2003	AL, AZ, AR, CA, GA, LA, MS, MO, NC, SC, TN, TX	lint plus seed	15.19	bale
Oats	2005	IL, IA, KS, MI, MN, NE, NY, ND, PA, SD, TX, WI	grain	0.59	bushel
Peanuts	2004	AL, FL, GA, NC, TX	nuts with pods	0.04	pound
Sorghum	2003	CO, KS, MO, NE, OK, SD, TX	grain	0.98	bushel
				14.76	ton
Soybeans	2006	AR, IL, IN, IA, KS, KY, LA, MI, MN, MS, MO, NE, NC, ND, OH, SD, TN, VA, WI	beans	3.55	bushel
Wheat	2004	CO, ID, IL, KS, MI, MN, MO, MT, NE, ND, OH, OK, OR, SD, TX, WA			
Winter			grain	1.13	bushel
Other spring			grain	1.39	bushel
Durum			grain	1.29	bushel

Notes: N = nitrogen. ARMS = USDA's Agricultural Resource Management Survey. The nitrogen uptake coefficients are from Lander et al. (1998). The coefficients for soft (1.02 lbs/bushel) and hard (1.23 lbs/bushel) winter wheat were averaged because the type of winter wheat produced was not available. To download estimates based on these data, or to learn more about the surveys, go to www.ers.usda.gov/data/arms/beta.htm.

Source: USDA, Economic Research Service using data from USDA's Agricultural Resource Management Survey (2003-06) and Lander et al. (1998).

Agricultural Resource Management Survey

USDA's Agricultural Resource Management Survey (ARMS) is an annual survey of farm and ranch operators administered by ERS and the National Agricultural Statistics Service (NASS). ARMS gathers data on field-level production practices, farm business accounts, and farm households. ARMS is a multiple-phase survey. In the fall, NASS interviews producers of major commodities, such as feed grains, food grains, or cotton, to collect information about production practices and land use on select fields. In the spring, NASS re-interviews farmers who successfully completed the fall survey. Spring data collection focuses on the structural and economic characteristics of the farm business and farm operator household. This approach helps link commodity production activities and conservation practices with the farm business and operator household.

Each phase of ARMS contains multiple versions of the survey questionnaire. The commonality of questions across versions provides one facet of data integration. In the fall data collection, the target commodity distinguishes questionnaires.

- ***Timing.*** Not applying nitrogen in the fall for a crop planted in the spring.
- ***Method.*** Injecting (placing fertilizer directly into the soil) or incorporating (applying to the surface and then discing the fertilizer into the soil) nitrogen rather than broadcasting on the surface without incorporation.

Form also plays a role in nitrogen management for improving NUE. However, available data do not allow for an assessment of the form of nitrogen fertilizer applied.

In this report, we evaluate nitrogen management only during the survey year covered by ARMS data. The loss of nitrogen to the environment in a particular year is mostly a function of current and not past management decisions. However, current management decisions have to account for past management, such as planting of a legume. The amount of commercial nitrogen applied is readily available from the ARMS responses; however, the amount of manure nitrogen must be estimated. We base these estimates on the quantity of raw manure applied, the form of the manure (liquid or solid), and the animal source of the manure. We also note whether the previous crop was a legume so as to account for the potential carryover of nitrogen.

A farm can fall into one of eight nitrogen management categories, defined by the three management decisions in a particular year:

1. All of the criteria are followed.
2. The rate and timing criteria are followed.
3. The rate and method criteria are followed.
4. The timing and method criteria are followed.
5. Only the rate criterion is followed.
6. Only the timing criterion is followed.
7. Only the method criterion is followed.
8. None of the criteria are followed.

How Many Acres Treated With Nitrogen Met the Criteria for Best Management Practices?

Because the crops covered in the analysis were surveyed in different years, we specify a reference year, 2006, to examine the extent to which best nitrogen management practices are being followed. Weights are calibrated so that the weighted sums of acres planted by the surveyed crop producers match USDA's published estimates of planted acres for 2006 (USDA, NASS, 2008). This provides reasonable baseline estimates under the assumption that the percentages of planted and treated acres and application rates by management category were stable between the survey reference years (see table 3.1) and 2006. We maintain this assumption throughout the analysis.

Sixty-nine percent of the 242 million acres planted to barley, corn, cotton, oats, peanuts, sorghum, soybeans, and wheat in 2006 were estimated to be treated with commercial and/or manure nitrogen (table 3.2). Corn accounted for an estimated 45 percent of the 167 million crop acres treated with nitrogen and 65 percent of the 8.7 million tons of nitrogen applied to these crops during 2006.

The application rate criterion was not met on over 53 million acres treated with nitrogen (32 percent). Cotton had the highest percentage of treated acres not meeting the rate criterion (47 percent), followed by corn (35 percent). However, corn accounted for 50 percent of all treated crop acres not meeting the rate criterion.

The timing criterion was not met on over 40 million treated acres (24 percent). About 34 percent of treated corn acres received commercial and/or manure nitrogen in the fall. These corn acres account for over 64 percent of all treated crop acres not meeting the timing criterion.

Table 3.2

Planted and nitrogen-treated acres, nitrogen applied, and the shares of treated acres and applied nitrogen that did not meet the rate, timing, or method criteria, by crop, 2006

Crop	Total			Did not meet rate		Did not meet timing		Did not meet method	
	Planted acres	Treated acres	Tons N	Treated acres	Tons N	Treated acres	Tons N	Treated acres	Tons N
	Thousands			*Percent*					
Barley	3,452	3,176	98	14	23	20	20	25	25
Corn	78,327	76,052	5,799	35	46	34	26	37	20
Cotton	15,274	12,566	591	47	61	18	11	32	24
Oats	4,168	2,748	93	33	49	28	32	42	41
Peanuts	1,243	737	14	1	7	16	11	39	29
Sorghum	6,522	5,370	220	24	31	16	16	27	21
Soybeans	75,522	16,827	248	3	31	28	56	45	43
Wheat	57,344	49,808	1,766	34	50	11	12	37	32
Total	241,852	167,285	8,829	32	47	24	23	37	24

Notes: N = nitrogen. These estimates are based on weighted sums, where the weights were calibrated so that the sums of planted acres for each crop based on the survey data match published estimates of planted acres for 2006 (USDA, 2008).

Source: USDA, Economic Research Service using data from USDA's Agricultural Resource Management Survey (2003-06), Phase II. See table 3.1 for details.

Nitrogen was not incorporated/injected on over 61 million treated crop acres (37 percent). These acres received 24 percent of all applied nitrogen. Soybeans (45 percent) had the highest percentage of acres not meeting the method criterion. However, corn accounted for about 46 percent of all treated acres not meeting the method criterion.

Corn acres make up nearly half of all acres that are in need of some type of improvement in nitrogen management, in that at least one of the three criteria is not met (fig. 3.1). Any policy aimed at improving nitrogen use efficiency would have to consider the factors driving management decisions in corn production.

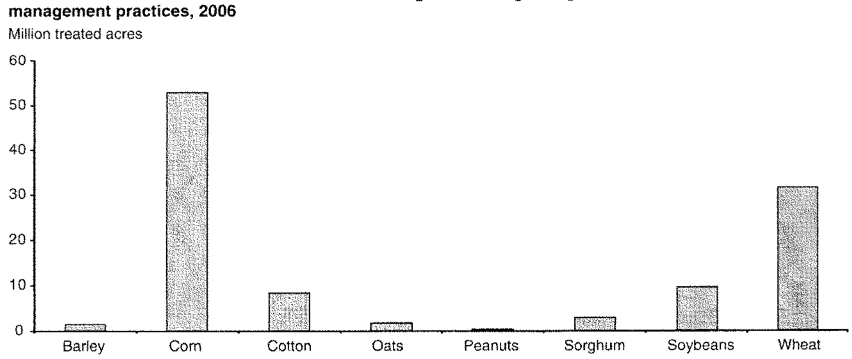
From a regional standpoint, the Corn Belt and Northern Plains dominate in terms of cropland not meeting the management criteria (figs. 3.2, 3.3). Not coincidentally, these are the primary corn-growing areas in the United States. However, in terms of nitrogen application in excess of the criterion rate, the Corn Belt and Lake States receive the greatest amounts of excess nitrogen (fig. 3.4).

As described in the previous chapter, NUE is highest when all three management criteria are met. Table 3.3 shows the percentage of treated acres in each nitrogen management category, as well as the degree to which excess nitrogen is applied in relation to the rate criterion. About 35 percent (58 million acres) of the treated acreage meet all three criteria. Corn has the smallest percentage of treated acres meeting all three criteria (30.4 percent). Because of the large amount of cropland planted to corn, this represents about half of all crop acres needing improvement in nitrogen management (rate, timing, or method). Only 4.2 percent of all treated acres do not meet any of the three criteria.

About 47 percent of all treated crop acres meet the method and timing criteria. Most of the acres exceeding the rate criterion do so by less than 50

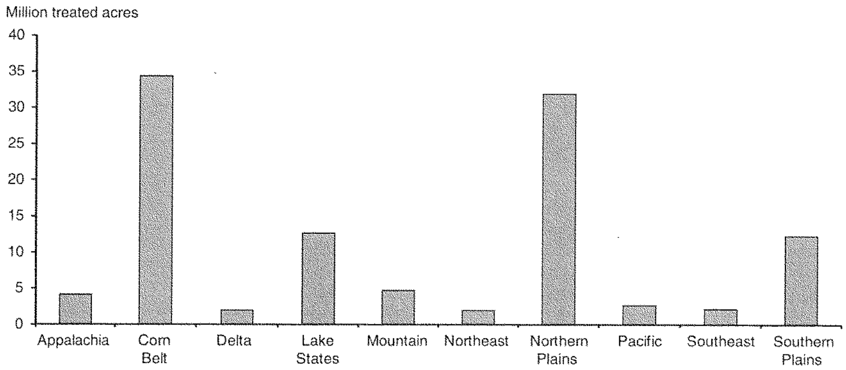
Figure 3.1

Acres treated with commercial and/or manure nitrogen not using nitrogen best management practices, 2006



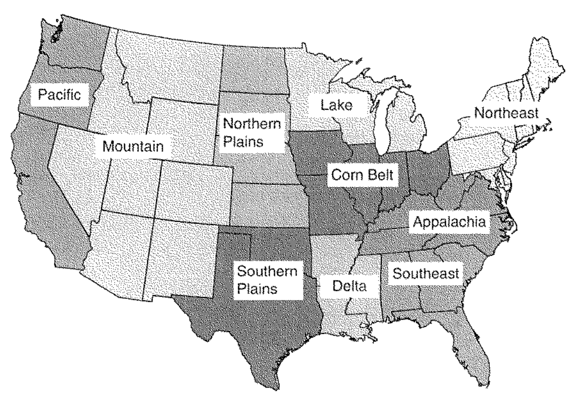
Source: USDA, Economic Research Service using data from USDA's Agricultural Resource Management Survey (2003-06), Phase II. See table 3.1 for details.

Figure 3.2
Acres treated with commercial and/or manure nitrogen not using nitrogen best management practices, by region, 2006



Source: USDA, Economic Research Service using data from USDA's Agricultural Resource Management Survey (2003-06), Phase II. See table 3.1 for details.

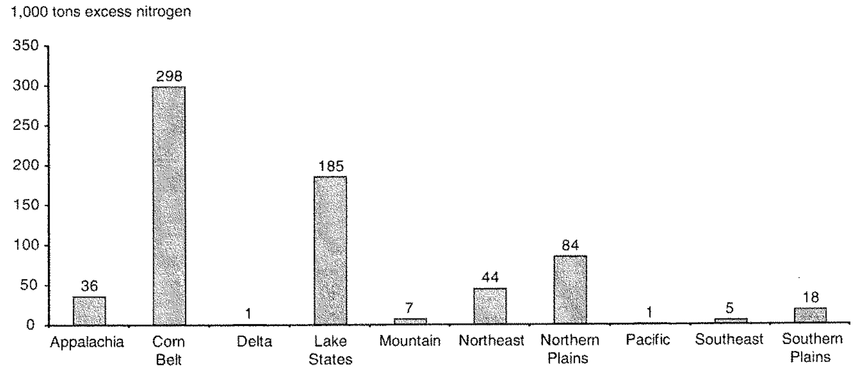
Figure 3.3
USDA farm production regions



Source: USDA, Economic Research Service.

percent. For example, about 14 percent of corn acres receive applications of 10 percent or less over the criterion rate. Reducing application rates on these acres so that the rate criterion is met would mean that nearly 80 percent of all corn acres would meet the rate criterion and that 35 percent of corn acres would meet all three criteria.

Figure 3.4
Total nitrogen applications above criterion rate by region, 2006



Note: Criterion rate defined as nitrogen removed at harvest plus 40 percent.
Source: USDA, Economic Research Service using data from USDA's Agricultural Resource Management Survey (2003-06), Phase II. See table 3.1 for details.

It should be noted that our findings differ somewhat from those reported by USDA's Conservation Effects Assessment Project (CEAP) assessment of the Upper Mississippi River Basin (USDA, 2010). The CEAP study reports smaller percentages of cropland meeting the nitrogen management criteria. The ERS study, however, examines nitrogen management for only the survey year. The CEAP analysis looks at nutrient management practices over an entire crop rotation, which may run from 2 to 5 years (see box, "CEAP Analysis of Nitrogen Management in the Upper Mississippi River Basin"). All three criteria had to be met in each year of the rotation for CEAP to consider the cropping system as having met the nitrogen management goal. The CEAP approach is stricter than that used by ERS.

Manure Use

Previous research has indicated that farms with animals tend to overapply nutrients to crops, primarily because of the large amount of manure produced on the farm needing disposal (Ribaudo et al., 2003; Gollehon et al., 2001). ARMS data provide additional evidence that manure use is associated with overapplication of nutrients. About 10 percent of crop acres treated with nitrogen (treated acres) received manure. Ninety-three percent of treated acres receiving manure did not meet all three criteria, compared with 62 percent of treated acres not receiving manure (table 3.4). Most of the cropland receiving manure was used to grow corn (72 percent). Over 95 percent of the corn acres receiving manure did not meet all three criteria, compared with 65 percent for corn acres not receiving manure.

Table 3.3
Percent treated acres by management category, crop, and degree of excess application, 2006

Rate criterion status	Timing or method criteria met: Timing and method	Timing	Method	Neither
	Percent of treated acres			
At or less than criterion rate				
Barley	52.0	16.4	13.0	4.3
Corn	30.4	15.0	12.0	6.2
Cotton	32.9	11.6	6.5	2.3
Oats	33.8	13.5	8.0	11.0
Peanuts	53.5	29.7	7.0	8.7
Sorghum	44.5	18.4	9.5	3.3
Soybeans	43.0	27.7	9.8	16.1
Wheat	36.8	22.2	5.2	1.7
Total	34.8	18.3	9.2	5.5
0 -10% over rate				
Barley	1.8	1.1	0.7	0.1
Corn	4.6	2.0	4.2	3.3
Cotton	6.6	3.5	3.7	0.7
Oats	1.2	1.2	0.0	0.1
Peanuts	0.3	0.0	0.0	0.0
Sorghum	3.7	0.3	1.1	0.1
Soybeans	0.0	0.1	0.1	0.0
Wheat	4.4	2.5	0.8	0.1
Total	4.1	2.0	2.5	1.6
10-50% over rate				
Barley	3.9	1.7	1.0	0.9
Corn	4.6	5.0	2.3	2.8
Cotton	10.4	7.2	1.8	0.8
Oats	6.4	2.3	0.5	1.6
Peanuts	0.1	0.0	0.0	0.0
Sorghum	6.6	1.9	1.7	0.3
Soybeans	0.0	0.2	1.1	0.6
Wheat	8.9	5.3	2.6	0.1
Total	5.9	4.5	2.1	1.5
50-100% over rate				
Barley	1.1	0.3	0.1	0.2
Corn	0.7	1.0	0.4	1.1
Cotton	3.3	4.0	1.3	0.5
Oats	3.6	1.9	0.4	1.3
Peanuts	0.0	0.4	0.0	0.0
Sorghum	1.7	0.3	0.0	0.0
Soybeans	0.1	0.1	0.1	0.2
Wheat	3.9	3.1	0.1	0.0
Total	1.9	1.7	0.3	0.6

-- *continued*

Table 3.3
Percent treated acres by management category, crop, and degree of excess application, 2006 (continued)

Rate criterion status	Timing or method criteria met: Timing and method	Timing	Method	Neither
	Percent of treated acres			
Greater than 100% over rate				
Barley	0.2	0.0	0.1	0.2
Corn	0.6	0.3	1.2	0.8
Cotton	1.5	0.9	0.2	0.2
Oats	2.2	4.7	1.3	4.3
Peanuts	0.3	0.0	0.0	0.0
Sorghum	4.3	2.0	0.1	0.0
Soybeans	0.4	0.0	0.0	0.0
Wheat	0.2	1.7	0.1	0.1
Total	0.7	0.9	0.6	0.5
Total not meeting rate criterion	12.6	9.1	5.5	4.2

Notes: Figures in bold meet the rate criterion. See the notes to table 3.2.
Source: USDA, Economic Research Service using data from USDA's Agricultural Resource Management Survey (2003-06), Phase II. See table 3.1 for details.

Other Considerations

The environmental impacts of low nitrogen use efficiency on the environment can be affected by different land management practices, such as the presence of underground tile drains and the use of filter strips or riparian buffers. Tile drainage plays a role in nitrogen losses from fields (David et al., 2010). Tile drainage lowers the water table, enabling fields that would otherwise be wet part of the year to be intensively cropped. These drained soils tend to be highly productive. Tiles, however, provide a rapid conduit for soluble nitrate, effectively bypassing any attenuation that may occur in the soil. ARMS data indicate that nearly 26 percent of treated cropland is tiled, most of this in corn production (table 3.5). Of particular interest is the degree to which nitrogen management on this vulnerable cropland is not using nitrogen BMP. ARMS data indicate that about 71 percent of tiled acres do not meet all three nitrogen management criteria. Most of these acres are in corn production. Much of the tile-drained cropland is located in the Mississippi River Basin, which has implications for hypoxia in the Gulf of Mexico.

Land management practices can mitigate nitrogen losses from fields. The use of filter strips or riparian buffers can reduce the amount of nitrogen lost to surface water bodies. Less than 10 percent of treated crop acres not meeting the rate, timing, or method criteria have filter strips that could reduce losses in runoff and subsurface flows (table 3.6). For corn, about 11 percent of acres not using nitrogen BMPs have filter strips that could mitigate losses to water, but significant improvements could still be made. Filter strips, however, do not address atmospheric losses and may not be effective if not sited or managed appropriately. In addition, buffers would be ineffective on the 26 percent of treated cropland that is tile drained.

CEAP Analysis of Nitrogen Management in the Upper Mississippi River Basin

Our assessment of nitrogen management on cropland using data from USDA's Agricultural Resource Management Survey (ARMS) has some similarities with the assessment of nutrient management on cropland in the Upper Mississippi River Basin (UMRB) conducted by the Conservation Effects Assessment Project (CEAP). The two studies also have some important differences. CEAP was initiated by USDA's Natural Resources Conservation Service, Agricultural Research Service, and Cooperative State Research, Education, and Extension Service (recently renamed the National Institute of Food and Agriculture). The goal of CEAP is to estimate conservation benefits from conservation investments and to provide research and an assessment on how to best use conservation practices in managing agricultural landscapes to protect and enhance environmental quality. The assessment of cultivated cropland in the UMRB is the first of a series of studies that will cover major crop-producing areas of the United States. Findings from the UMRB study are available at www.nrcs.usda.gov/technical/nri/ceap/umrb/index.html.

Both analyses assess baseline nitrogen management on cropland according to three criteria: rate, timing, and method. The definitions we used for each are based on those used in the CEAP analysis. Both studies used a survey to collect data on nutrient management practices. The major difference between our analysis using ARMS data and the CEAP analysis is how the criteria were applied. ARMS collects information about cropping practices during a single crop year. Our analysis, therefore, based the assessment of nitrogen management on practices used to produce the crop sampled by the survey. The CEAP analysis focused on cropping systems, which could be up to 5 years in length and contain several different crops. Data were collected on production practices used each year of the crop rotation. CEAP used these data to evaluate the entire rotation, not just the crop grown during the year the survey was conducted. If the rate, timing, or method criteria were not met during any year of the rotation, then that sample point was identified as not meeting the nitrogen management criteria. This approach is more stringent than the one used in our analysis. For example, assume corn and soybeans were on a 2-year rotation and that corn was grown during the year the ARMS and CEAP surveys were conducted. In our analysis, if the nitrogen application rate on corn met the rate criterion, then that corn sample was identified as such. In the CEAP study, the nitrogen application rate on both the corn and the previous year's soybean crops were assessed. If the application rate on corn met the rate criterion but excess nitrogen was applied to soybeans, then the rotation was identified as not meeting the criterion. This leads to the CEAP assessment reporting a smaller percentage of crop acres meeting the rate criterion than we would report. Overall, the CEAP analysis reports fewer crop acres meeting the rate, timing, and method criteria than does the ERS report.

Nitrogen Management on U.S. Corn

A high percentage of crop acres meet at least some of the nitrogen management criteria (see table 3.3). Corn, however, meets all three criteria least often. Corn is the most intensive user of nitrogen and the most widely planted crop. Improvements in rate, timing, and/or application method are needed on 70 percent of corn acres to improve NUE. In addition, growth in corn demand due to the biofuels mandate suggests that corn acreage may increase

Table 3.4
Percent treated crop acres receiving commercial or manure nitrogen that did not meet the rate, timing, and method criteria, by crop, 2006

Crop	Planted acres	Treated acres	Acres treated with commercial N only		Acres treated with commercial and manure N		Acres treated with manure N only	
	Thousands		*Percent of all treated acres*	*Percent vulnerable*[1]	*Percent of all treated acres*	*Percent vulnerable*	*Percent of all treated acres*	*Percent vulnerable*
Barley	3,452	3,176	94	45	4	96	2	89
Corn	78,327	76,052	84	65	14	96	2	91
Cotton	15,274	12,566	96	67	3	85	1	29
Oats	4,168	2,748	78	59	9	88	13	92
Peanuts	1,243	737	93	46	5	52	2	41
Sorghum	6,522	5,370	98	55	1	98	1	49
Soybeans	75,522	16,827	85	51	2	100	13	91
Wheat	57,344	49,808	99	63	1	92	0	28
Total	241,852	167,285	90	62	7	96	3	86

[1]Vulnerable acres are those not meeting the rate, timing, and method criteria.

Notes: N = nitrogen. See notes to table 3.2. These estimates were weighted by the total amount of nitrogen applied by management category.

Source: USDA, Economic Research Service using data from USDA's Agricultural Resource Management Survey (2003-06), Phase II. See table 3.1 for details.

Table 3.5
Nitrogen-treated acres with tile drainage that did not meet the rate, timing, or method criteria by crop, 2006

Crop	Treated acres: Total	Treated acres: With tile drains	Tile-drained acres that do not meet the rate, timing, or method criteria
	Thousands		*Percent*
Barley	3,176	42	43
Corn	76,052	34,738	70
Cotton	12,566	583	71
Oats	2,748	216	66
Peanuts	737	40	44
Sorghum	5,370	46	43
Soybeans	16,827	5,690	69
Wheat	49,808	1,644	94
Total	167,285	43,000	71

Notes: See notes to table 3.2.

Source: USDA, Economic Research Service using data from USDA's Agricultural Resource Management Survey (2003-06), Phase II. See table 3.1 for details.

in the future, along with the intensity of corn production. Together, these factors could increase reactive nitrogen emissions to the environment unless nitrogen use efficiency is improved.

An examination of an additional year of survey data collected during the 2001 growing season and disaggregated regionally helps determine if management has undergone recent changes and if such changes vary by region. The share of corn acres not meeting the rate criterion declined from 41 to 35 percent between 2001 and 2005 (table 3.7). This finding is in

Table 3.6
Nitrogen-treated acres not meeting the rate, timing, or method criteria that have filter strips, by crop, 2006

Crop	Number of acres not meeting rate, timing or method criteria	No. of acres not meeting rate, timing, or method criteria with filter strips	% of acres with filter strips not meeting criteria
Barley	1,523	68	4
Corn	52,910	5,909	11
Cotton	8,432	397	5
Oats	1,818	99	5
Peanuts	343	42	12
Sorghum	2,983	64	2
Soybean	9,600	475	5
Wheat	31,475	2,530	8
Total	109,084	9,584	9

Notes: See notes to table 3.2.
Source: USDA, Economic Research Service using data from USDA's Agricultural Resource Management Survey (2003-06), Phase II. See table 3.1 for details.

agreement with those of other reports on improving nitrogen use efficiency based on steady application rates and increased corn yields (Turner et al., 2007). Improvements in rate were seen in all regions except Appalachia and the Southeast. Notable improvements were seen in the Corn Belt, Lake States, and Northeast. Timing and method, however, did not show similar improvements in the more recent data. For most regions, the percentage of corn acres not meeting these two criteria increased.

Changing Management May Result in Environmental Tradeoffs

Changing management practices may improve nitrogen use efficiency, but the environmental outcomes may not always be desirable. We use the new Nitrogen Loss and Environmental Assessment Package with GIS (Geographic Information System) capabilities (NLEAP-GIS) model to assess how changes in nitrogen management practices on corn affect the losses of nitrate (to water), nitrous oxide (to air), and ammonia (to air) (Shaffer et al., 2010; Delgado et al., 2010a). Of particular interest is the extent to which tradeoffs in environmental outcomes might occur as overall nitrogen use efficiency is improved. See appendix 2 for more details on NLEAP.

Because NLEAP is a field-level model, we selected eight different soils in four States (Arkansas, Ohio, Pennsylvania, and Virginia) to assess changes in nitrogen emissions to the environment from management changes in nonirrigated corn production.[1] Four of the soils are type A or B soils (well drained), and four are type D soils (relatively poorly drained). For each soil, we examined two rotations (corn-corn and corn-soybeans), two tillage practices (conventional and no-till), and two sources of nitrogen (inorganic fertilizer and inorganic fertilizer + animal manure). The slopes for these soils were 0 to 6 percent, with low erosion potential.

[1]These four States were selected because they present a wide variation in growing conditions and because the data necessary for running NLEAP were already developed.

For each soil/rotation/tillage/nitrogen-source combination, eight different scenarios were modeled with NLEAP, each representing one of the combi-

Table 3.7
Nitrogen-treated acres and the shares that did not meet the rate, timing, or method criteria for corn, 2001 and 2005

Region	Treated acres		Did not meet rate		Did not meet timing		Did not meet method	
	2001	*2005*	*2001*	*2005*	*2001*	*2005*	*2001*	*2005*
	Thousands		*Percent of treated acres*					
Appalachia	1,925	2,118	52	66	12	16	56	78
Corn Belt	35,087	39,145	46	38	41	41	39	34
Lake States	12,965	13,958	46	34	37	41	36	30
Mountain	1,243	1,018	18	14	9	20	33	50
Northeast	2,696	2,477	42	32	39	40	54	53
Northern Plains	16,962	18,293	27	28	10	15	36	45
Southeast	280	286	39	50	27	29	41	55
Southern Plains	1,708	2,109	31	32	45	38	33	18
Total	72,868	79,404	41	35	32	34	38	37

Notes: In both years, corn producers were surveyed in Colorado (Mountain); Kansas, Nebraska, North Dakota, and South Dakota (Northern Plains); Texas (Southern Plains); Michigan, Minnesota, and Wisconsin (Lake States); Illinois, Indiana, Iowa, Missouri, and Ohio (Corn Belt); New York and Pennsylvania (Northeast); Kentucky and North Carolina (Appalachia); and Georgia (Southeast). These estimates are based on weighted sums, with the weights recalibrated so that the weighted sums of planted acres for each crop based on the survey data match estimates for 2001 and 2005 (USDA, 2008).

Source: USDA, Economic Research Service using data from USDA's 2001 and 2005 Agricultural Resource Management Survey, Phase II.

nations of nitrogen management criteria outlined in table 3.4. Therefore, 64 different scenarios were modeled for each soil.

A recommended application rate was specified for each soil/cropping system combination, based on local agronomic recommendations, as described by Espinoza and Ross (2008) for Arkansas, Alley et al. (2009) for Virginia, Beegle and Durst (2003) for Pennsylvania, and Vitosh et al. (1995) for Ohio. For the purposes of this analysis, overapplication was set at 75 percent more than the recommended rate (at the upper end of overapplication found in the ARMS data and reported in table 3.3). For example, if the recommended rate was 132 pounds of N per acre, the overapplication scenario used 231 pounds (see app. 2).

The modeled policy goal is that all three nitrogen management criteria be met. For demonstration purposes, we used the NLEAP results to assess the potential emissions tradeoffs when method, timing, timing and method, or rate BMPs are adopted by corn farmers. For example, to evaluate the tradeoff when timing is improved (rate and method criteria are already met), we compare the NLEAP results for the rate and method BMPs with the results for the rate, timing, and method BMPs. Each cropping system is evaluated separately. Because of the volume of results for the eight soils modeled, we present only those from the two soils in Ohio (tables 3.8a-d). Results for the other States are similar, in terms of the direction of changes.

All the scenarios show the expected changes in total nitrogen losses, with reductions indicating improvements in NUE. The NLEAP results were consistent with the expectation that nitrogen emissions are minimized when all three criteria are met. Since nitrogen cycles through different forms and ecosystems, the long-term environmental benefits of reducing total nitrogen

Table 3.8a

Changes in nitrogen losses resulting from improvements in nitrogen management, NLEAP estimates - Ohio - Type A soil - conventional tillage

Management improvement	Without manure Criterion rate=132 pounds N per acre				With manure Criterion rate=198 pounds N per acre*			
	Total	*NO_3*[5]	*N_2O*[6]	*NH_3*[6]	*Total*	*NO_3*	*N_2O*	*NH_3*
	Pounds of N per acre							
Continuous corn								
Method[1]	-32.8	7.0	-1.7	-38.1	-17.0	24.6	-1.2	-40.4
Timing[2]	-16.6	-17.4	0.8	+	-16.6	-17.6	1.0	+
Method+timing[3]	-33.0	-9.1	0.4	-23.7	-18.6	11.4	0.8	-30.8
Rate[4]	-69.3	-50.6	-0.9	-17.7	-105.1	-81.0	-1.3	-22.9
	Criterion rate=102 pounds N per acre				*Criterion rate=153 pounds per acre**			
Corn-soybean								
Method[1]	-16.6	0.4	-0.8	-16.2	-14.7	3.8	-0.4	-18.1
Timing[2]	-5.7	-6.0	0.3	+	-5.2	-5.6	0.4	+
Method+timing[3]	-13.1	-4.2	0.1	-9.0	-13.8	0.5	0.3	-14.6
Rate[4]	-15.7	-8.6	-0.4	-6.8	-37.2	-26.0	-0.6	-10.6

Note:*Manure is applied every other year. Criterion rate is met on average over 2-year period. + indicates a positive but very small change.
N = nitrogen. NO_3 = nitrogen trioxide. N_2O = nitrous oxide. NH_3 = ammonia.

[1]Timing and rate best management practices (BMP) are already in place.

[2]Method and rate BMPs are already in place.

[3]Rate BMP is already in place.

[4]No BMPs are in place.

[5]Nitrate loss to water (primarily through leaching but often ends up in surface water).

[6]Ammonia and nitrous oxide loss to atmosphere.

Source: USDA, Economic Research Service.

are clear. However, some of the tradeoffs between different forms of nitrogen could pose environmental problems. Adopting injection/incorporation always increases nitrate leaching, sometimes substantially (more than doubling leaching in some cases). Similarly, shifting applications from fall to spring (without changing application rate) reduces nitrate losses and total nitrogen losses but increases N_2O emissions as applications are shifted to generally warmer, wetter conditions, which is consistent with the findings of Delgado et al. (1996), Rochette et al. (2004), and Hernandez-Ramirez et al. (2009). Because of concerns over greenhouse gas (GHG) emissions, this outcome would have to be carefully considered when making recommendations to improve nitrogen use efficiency.

Adopting both method and timing again produces mixed results. NH_3 emissions are always reduced. Leaching is generally reduced, but in some cases where manure is used, it may increase. N_2O emissions almost always increase, from 5 to 50 percent, depending on the situation. In agreement with basic principles of nitrogen management, only reducing the application rate guarantees that losses of all three forms of reactive nitrogen are reduced (Mosier et al., 2002; Meisinger and Delgado, 2002). Based on these findings, a recommendation could be that in areas where leaching to drinking water sources is a concern, improvements in nitrogen use efficiency could focus on application rate reductions or improvements in timing.

Table 3.8b

Changes in nitrogen losses resulting from improvements in nitrogen management, NLEAP estimates – Ohio – Type A soil - no-till

Management improvement	Without manure Criterion rate=116 pounds N per acre				With manure Criterion rate=174 pounds N per acre*			
	Total	*NO_3*[5]	*N_2O*[6]	*NH_3*[6]	*Total*	*NO_3*	*N_2O*	*NH_3*
	Pounds of N per acre							
Continuous corn								
Method[1]	-29.6	5.6	-1.1	-34.1	-15.6	23.5	-0.3	-38.8
Timing[2]	-27.5	-28.6	1.1	+	-16.2	-17.3	1.1	+
Method+timing[3]	-40.6	-20.8	1.1	-20.9	-27.3	0.2	1.3	-28.8
Rate[4]	-53.7	-37.3	-0.6	-15.8	-85.0	-63.8	-0.8	-20.3
	Criterion rate=86 pounds N per acre				*Criterion rate=129 pounds N per acre**			
Corn-soybean								
Method[1]	-14.0	0.7	-0.8	-13.9	-12.7	4.7	-0.1	-17.3
Timing[2]	-9.9	-10.3	0.4	+	-8.6	-9.0	0.4	+
Method+timing[3]	-14.9	-7.6	0.3	-7.6	-15.1	-2.2	0.5	-13.4
Rate[4]	-15.5	-9.5	-0.3	-5.7	-28.2	-18.7	-0.4	-9.1

Note:*Manure is applied every other year. Criterion rate is met on average over 2-year period. + indicates a positive but very small change. N = nitrogen. NO_3 = nitrogen trioxide. N_2O = nitrous oxide. NH_3 = ammonia.

[1]Timing and rate best management practices (BMP) are already in place.

[2]Method and rate BMPs are already in place.

[3]Rate BMP is already in place.

[4]No BMPs are in place.

[5]Nitrate loss to water (primarily through leaching but often ends up in surface water).

[6]Ammonia and nitrous oxide loss to atmosphere.

Source: USDA, Economic Research Service.

Summary

The survey data indicate that in 2006, all of the nitrogen management criteria were met on an estimated 35 percent of the crop acres treated with commercial and/or manure nitrogen.[2] In addition, a high percentage of treated acres met at least some of the nitrogen management criteria. Among all crops, corn met the criteria the least, and corn accounts for 50 percent of the treated acres upon which one or more improvements to management could be made to improve nitrogen use efficiency. Improvements in rate, timing, and/or method might be needed on 67 percent of corn acres.

NLEAP-GIS simulation results reported in the literature show that changing timing or method of application could potentially increase the loss of one type of nitrogen compound, even if total nitrogen emissions decline and NUE increases. NLEAP modeling indicates that only reducing application rates ensures that all nitrogen emissions decrease, in agreement with established principles of nitrogen management.

[2]Recall that this adoption rate is higher than that reported by the USDA-NRCS CEAP analysis, which considers adoption over multiyear rotations (see box on page 17).

Table 3.8c

Changes in reactive nitrogen losses resulting from improvements in nitrogen management, NLEAP estimates – Ohio - Type D soil - conventional till

Management improvement	Without manure Criterion rate=132 pounds N per acre				With manure Criterion rate=198 pounds N per acre*			
	Total	*NO_3*[5]	*N_2O*[6]	*NH_3*[6]	*Total*	*NO_3*	*N_2O*	*NH_3*
	Pounds of N per acre							
Continuous corn								
Method	-28.3	0.7	-5.0	-24.0	-20.0	12.9	-3.1	-29.8
Timing	-8.1	-9.4	1.3	+	-12.1	-13.5	1.4	+
Method+timing	-20.2	-7.6	1.2	-13.8	-17.2	4.6	1.7	-23.5
Rate	-56.3	-44.1	-1.8	-10.4	-91.3	-70.9	-3.0	-17.4
	Criterion rate=102 pounds N per acre				*Criterion rate=153 pounds N per acre**			
Corn-soybean								
Method	-14.7	0	-4.1	-10.6	-16.2	1.3	-2.2	-15.3
Timing	-1.9	-2.5	0.6	+	-2.7	-3.3	0.6	+
Method+timing	-6.8	-2.1	0.5	-5.2	-12.5	-0.4	0.8	-12.9
Rate	-9.3	-4.7	-0.7	-3.9	-27.8	-17.1	-1.4	-9.3

Note:*Manure is applied every other year. Criterion rate is met on average over 2-year period. + indicates a positive but very small change. N = nitrogen. NO_3 = nitrogen trioxide. N_2O = nitrous oxide. NH_3 = ammonia.

[1]Timing and rate best management practices (BMP) are already in place.

[2]Method and rate BMPs are already in place.

[3]Rate BMP is already in place.

[4]No BMPs are in place.

[5]Nitrate loss to water (primarily through leaching but often ends up in surface water).

[6]Ammonia and nitrous oxide loss to atmosphere.

Source: USDA, Economic Research Service.

Table 3.8d

Changes in reactive nitrogen losses resulting from improvements in nitrogen management, NLEAP estimates –Ohio - Type D soil - no-till

Management improvement	Without manure Criterion rate=116 pounds N per acre				With manure Criterion rate=174 pounds N per acre*			
	Total	*NO_3*[5]	*N_2O*[6]	*NH_3*[6]	*Total*	*NO_3*	*N_2O*	*NH_3*
	Pounds of N per acre							
Continuous corn								
Method	-35.4	0.7	-1.4	-34.4	-25.8	13.6	-0.3	-39.1
Timing	-21.4	-22.0	0.6	+	-11.1	-11.8	0.7	+
Method+timing	-38.8	-18.3	0.6	-21.1	-32.2	-4.1	1.2	-29.3
Rate	-37.3	-20.4	-1.0	-15.9	-66.3	-44.2	-1.8	-10.4
	Criterion rate=86 pounds N per acre				*Criterion rate=129 pounds N per acre**			
Corn-soybean								
Method	-14.5	0.3	-0.8	-14.0	-16.0	1.6	0	-17.6
Timing	-7.2	-7.4	0.2	+	-6.2	-6.5	0.3	+
Method+timing	-13.3	-5.9	0.2	-7.6	-16.7	-3.7	0.6	-13.6
Rate	-10.1	-4.0	-0.4	-5.7	-20.4	-10.5	-0.7	-9.2

Note:*Manure is applied every other year. Criterion rate is met on average over 2-year period. + indicates a positive but very small change. N = nitrogen. NO_3 = nitrogen trioxide. N_2O = nitrous oxide. NH_3 = ammonia.

[1]Timing and rate best management practices (BMPs) are already in place.

[2]Method and rate BMPs are already in place.

[3]Rate BMP is already in place.

[4]No BMPs are in place.

[5]Nitrate loss to water (primarily through leaching but often ends up in surface water).

[6]Ammonia and nitrous oxide loss to atmosphere.

Source: USDA, Economic Research Service.

Chapter 4

Policy Instruments for Nitrogen Reduction

Based on ARMS data, 65 percent of surveyed cropland, or 109 million acres, is in need of improved nitrogen management. Given nitrogen's effects on the environment, improving nitrogen management on vulnerable lands is a policy goal, both nationally and regionally.

Farmers adjust the management of their crops for a variety of reasons. Economic factors, such as input or output price changes, may lead to more (or less) careful use of nitrogen inputs. Farmers may also have to consider various policy-based incentives for adopting practices that improve nitrogen management. Over the years, policy instruments have been employed to improve the management of agricultural inputs and resources. USDA conservation programs rely primarily on subsidies for management practices and education. USDA also employs compliance mechanisms to protect wetlands and highly erodible soils. The U.S. Environmental Protection Agency (EPA) is using regulations to address nutrient management on certain confined animal feeding operations. A few States have used nitrogen fertilizer taxes to raise revenue for nutrient management programs. Such policy approaches may have a role to play in increasing the number of crop acres that meet the three nitrogen management criteria described earlier.

Provide Information (Education)

A lack of knowledge about their performance may be preventing farmers from using the most efficient nutrient management practices. Education is used to provide producers with information on how to farm more efficiently. Its success depends on alternative practices being more profitable to farmers than current practices (Ribaudo and Horan, 1999). Two practices that can lead to more efficient fertilizer use are soil testing and tissue testing. These tests provide information that reduces some of the uncertainty surrounding nutrient availability and enables producers to apply fertilizer at rates more consistent with plant needs and high nitrogen use efficiency.

ERS research supports previous findings that nitrogen testing is having the desired effect on nitrogen application rates for certain nitrogen users. Data from the 2001 and 2005 ARMS indicate that about 21 percent of corn farmers used a soil or tissue test as a basis for their level of nitrogen application (table 4.1). Farmers who used commercial nitrogen followed the recommendations closely. In our sample, their mean application rate of nitrogen was 136 lbs per acre, and the mean recommended rate based on a nitrogen soil test was 137 lbs per acre (table 4.2).

Compliance with the soil test, however, was much worse for farmers who used both manure and commercial fertilizer. In their case, the recommended nitrogen application rate was 123 pounds per acre. And while farmers applied only 85 pounds per acre of commercial fertilizer, total nitrogen application rates were 175 pounds per acre when manure was added.

We compared nitrogen application rates of those farmers who use soil N and tissue tests with those who do not using regression analysis that accounts

Table 4.1
Factors influencing farmers' nitrogen fertilizer application decision

Application used	2001	2005
	Percent of farmers	
Soil or tissue test	18.8	27.0*
Crop consultant recommendation	13.0	17.6*
Fertilizer dealer recommendation	28.7	41.2*
Extension service recommendation	3.2	4.6*
Cost of nitrogen and/or expected commodity price	11.4	17.3*
Routine practice	70.9	71.7*
	Number	
Observations	1,646	1,344

*Statistically different from 2001 at the 1-percent level, based on pairwise two-tailed delete-a-group Jackknife t-statistics (Dubman, 2000)

Source: USDA, Economic Research Service using data from USDA's 2001 and 2005 Agricultural Resource Management Survey, Phase II, Cost of Production Practices and Costs Report.

for a number of production, land, and operator characteristics (see app. 3). Findings show that soil nitrogen testing has a statistically significant impact on nitrogen application rates. In the case of farmers who use commercial nitrogen exclusively, those who tested the soil applied 73.9 pounds per acre less than those who did not, all else equal. Other studies have found soil tests to be of similar effectiveness (Wu and Babcock, 1998; Musser et al., 1995).

An information-based approach can meet nitrogen efficiency goals only if the information provided leads to increased profits for farmers (Ribaudo and Horan, 1999). As long as there are expectations that more efficient nitrogen management leads to increased risk or higher costs, then nitrogen management goals are unlikely to be met with information alone. However, information has proven valuable in support of other policy goals. Education can reduce the cost of adopting nitrogen BMPs required by regulation or funded through financial incentives. For example, Bosch et al. (1995) found that education affected the outcomes associated with a regulation requiring nitrogen testing in Nebraska. Producers did not use the information provided by testing unless they received education assistance.

Financial Incentives

Financial assistance is an important tool used in many USDA conservation programs to promote the adoption of BMPs. Program effectiveness depends on how farmers respond to the incentive being offered. When a farmer accepts a payment in return for adopting a management practice, he or she is signaling that the payment at least represents the economic cost of implementing the practice, sometimes referred to as the willingness-to-accept. Generally, only the producer knows the true cost. This makes it difficult for program managers to find the minimum payment rate that entices enough producers into the program to achieve the particular environmental goal at least cost.

Table 4.2
Influence of soil/tissue nitrogen testing on fertilizer application rates for corn, with and without manure use, 2001 and 2005

For farmers using a soil test	Required nitrogen based on expected yield[1]	Soil test recommended nitrogen	Commercial nitrogen applied	Total nitrogen applied (commercial + manure)
		Pounds of nitrogen per acre		
Commercial nitrogen with manure Observations = 154	152	123	85†	175†
Commercial nitrogen without manure Observations = 645	165	137	136	136

[1]Based on nitrogen removed in expected harvest plus 40 percent to account for unavoidable nitrogen losses.

†Means are statistically different from the recommended nitrogen amount at the 1-percent level, based on pairwise two-tailed delete-a-group Jackknife t-statistics (Dubman, 2000).

Source: USDA, Economic Research Service using data from USDA's 2001 and 2005 Agricultural Resource Management Survey, Phase II, Cost of Production Practices and Costs Report.

USDA's NRCS supports management practices that specifically address fertilizer application rate, timing, or method in their standards. The Environmental Quality Incentives Program (EQIP) is the largest USDA program that provides producers with technical and financial assistance for implementing and managing BMPs on working farmland. Management practices supported by EQIP that can influence nitrogen use efficiency include nutrient management and waste utilization (for manure). Implementing a nutrient management plan directly affects measures of stewardship. Nutrient management planning addresses the amount, source, placement, form, and timing of the application of plant nutrients and soil amendments (USDA, NRCS, 2006). Further, the practice requires the application rate be based on an assessment of plant-available nitrogen developed through Land Grant University soil and tissue tests or recognized industry practices. Waste utilization guidelines specify that rates of application must be compatible with the soil's ability to absorb and hold the waste, and methods of incorporation are prescribed for liquid manure forms to prevent nutrients from rising to the surface.

Data from EQIP contracts in force for year 2008 show that participating farmers accepted an average payment of $8.88 per acre for adopting nutrient management (table 4.3). A higher per acre payment induced farmers to adopt a waste utilization practice ($14.75). Relatively few corn farm operations have livestock or a direct source of manure (organic) fertilizer, and, as reported later, the practice can be more costly to farmers than using commercial (inorganic) fertilizer.

A focus on the Corn Belt reveals variation in the accepted payments for the two practices (table 4.3). The variation may stem from cost differences within the region that are driven by local conditions, which, in turn, influence the State-level payment rate for the practice. To examine how management practices can affect a farm's cost of operations, we estimate a cost function using a generalized linear regression model estimated with 2001 ARMS data (see app. 4).[3] Model results show that several conservation practices have

[3]Because we are comparing 2001 costs with 2008 payments, we inflate 2001 costs using the U.S. Bureau of Labor Statistics' Consumer Price Index.

Table 4.3
Per acre average EQIP payments for conservation practices, 2008

Practice	All States	Corn Belt				
		Illinois	Indiana	Iowa	Missouri	Ohio
		Dollars per acre				
Nutrient management[1]	8.88	9.75	7.47	6.12	13.90	10.91
Waste utilization[2]	14.75	25.95	25.84		10.90	5.83

[1]Nutrient management planning addresses the amount, source, placement, form, and timing of the application of plant nutrients and soil amendments.

[2]Waste utilization guidelines specify that rates of application must be compatible with the soil's ability to absorb and hold the animal waste, and methods of incorporation are prescribed for liquid manure forms to prevent nutrients from rising to the surface.

Notes: Blank cells indicate no contracts for such practice in that State.

Source: USDA, Economic Research Service using contract data from USDA's Environmental Quality Incentives Program, fiscal years 1997-2008, payments made in fiscal year 2008.

little effect, on average, on the cost of operation relative to other methods of management. For example, the difference in operation costs for farms using nutrient management and for farms not using these practices is not statistically significant.

Based on results from our cost analysis, we also find that using manure as a nitrogen source costs roughly $26.84 more per acre than using only commercial fertilizer. However, we observe a national average per acre EQIP payment for the waste utilization of $14.75, and only two States in the Corn Belt (Illinois and Indiana) have payment levels that approach the estimated cost figure. The results suggest that the EQIP rate is insufficient to entice farmers who are not using manure to begin doing so in an environmentally sensitive manner. However, farms with livestock or poultry need to dispose of the waste. Therefore, rather than be a practice by choice, waste utilization may be a practice that complements the necessary disposal of manure, and a payment that covers increased production costs may not be a necessary condition for the willingness to adopt the practice.

Not all farmers require a cost share to adopt conservation practices. Cooper and Keim (1996) use farmer surveys to conclude that 12 to 20 percent of farmers may be willing to adopt practices such as split fertilizer applications and nutrient testing without financial assistance but do not do so because they lack information or are uncertain about the practices' economic performance. However, they also find that the adoption rate would not increase beyond 30 percent unless subsidy rates were substantially increased. A farmer's perception of the effectiveness of a practice can also influence the decision to adopt. Evidence from Lichtenberg and Lessley (1992) suggests that farmers may need more than a cost share to overcome perceptions of conservation practices and the state of environmental quality off-site.

In some cases, farmers are willing to adopt conservation practices that reduce profits if they believe that others will benefit from the subsequent change in environmental quality (Bishop et al., 2010; Chouinard et al., 2008). For example, based on survey responses from the State of Washington, Chouinard et al. (2008) conclude that farmers would be willing to forgo up to $4.52 (median value estimate) in per acre annual profits to implement soil-conserving stewardship practices.

The scope of a program's coverage is an important consideration for policymakers and program managers evaluating the adequacy of the financial incentives offered to program participants. In 2008, the financial incentives from EQIP encouraged farmers to enroll 4 million acres in the program's nutrient management practice. However, because participation in the program is voluntary, it is not known if the cropland most in need of treatment was enrolled.

We can use the data from EQIP and table 3.3 to estimate the cost to improve nitrogen use efficiency on those acres needing additional treatment. About 35 percent of all crop acres meet all three criteria, which means that over 108 million acres of cropland are not using nitrogen BMPs. Applying the average payment rate for nutrient management ($8.88 per acre) to all acres needing improved management implies annual EQIP payments of $959 million. However, the findings from Cooper and Keim (1996) suggest that higher rates would be needed to entice a sizable percentage of farmers to voluntarily enroll in a program. Assuming a payment rate 50 percent higher results in program expenditures of $1.4 billion. This is roughly the current annual budget for EQIP.

Given the potential cost of treating the entire 108 million acres of cropland not using nitrogen BMPs, which groups might be most important to address first? We previously reported that manure users generally apply much more total nitrogen to the field than farmers who exclusively apply commercial nitrogen. Providing financial assistance for nutrient management on the 7.7 million acres that received manure and failed to meet the rate criterion would cost between $68.4 and $103 million per year.

Off-Site Filtering for Reducing Nitrogen Losses From Fields

Similar to its efforts aimed at improving nitrogen use efficiency on working lands, the Government can provide financial incentives for installing management practices that capture nitrogen after it leaves a field, primarily nitrogen in water. This analysis estimates and evaluates the cost effectiveness of two such measures, wetlands restoration and vegetative filter strips (VFS), assuming that funding is targeted to areas where nitrogen removal is likely to be most effective.

The Costs of Nitrogen Capture by Restoring Wetlands

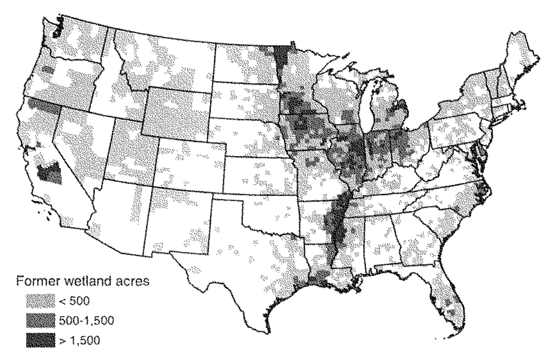
Our analysis of wetlands restoration focuses on the Glaciated Interior Plains (GIP), where models of wetlands nitrogen removal have been developed. The GIP includes major parts or all of Ohio, Minnesota, Wisconsin, Michigan, Iowa, Illinois, and Indiana—major corn-producing States. This area is also an important source of nitrogen that reaches the Gulf of Mexico and contributes to the hypoxic zone (Goolsby et al., 2001; Robertson et al., 2009). Wetlands in other parts of the United States can also reduce nitrogen loadings. But, because of regional differences in ecosystems, we do not extrapolate our findings to other areas.

Wetlands once made up a large portion of land on the GIP (fig. 4.1). Water tables were lowered to facilitate crop production by installing underground tile and surface drainage systems. Such drainage systems become conduits for the rapid movement of nitrate from fields to water resources.

The costs of creating wetlands vary widely as do nitrogen removal rates on wetlands. Costs are driven by the cost of the land and the cost of restoring wetland ecosystems. Nitrogen removal depends on the rate of nitrogen inflow, nitrogen concentration, seasonal variations in flow, wetland size, and other factors.

We use the USDA Wetland Reserve Program (WRP) contract data for the GIP to estimate multinomial land and restoration cost functions (see app. 5). With these functions, we generate county-level cost estimates throughout the GIP. The objectives of the WRP are to enhance, restore, and preserve wetlands. As of October 1, 2009, the WRP enrolled 2.18 million acres, with wetlands in every State. Along with the land and restoration cost variables, the WRP contract data contain information on the size and the county location of each contract. The land (wetland easement) cost variable represents the difference between the agricultural value of the land and the value of the land with a wetland easement. The easement requires that the landowner maintain the health of the ecosystem. Data for other variables in our analysis come from the NASS agricultural census. Across the counties within the GIP, wetland easement costs range from $1,490 to $3,030 per acre, as generated by our estimated land cost function. Expected wetland restoration costs range from $506 to $602 per acre. Annualizing over perpetuity with a discount rate of 5 percent, we estimate that the median annual expected cost of restoring and preserving wetlands is $153 per acre per year (table 4.4). Because marginal costs are less than average costs, one can expect average per acre

Figure 4.1
Historical wetlands converted to cropland, by county, 1997



Source: USDA, Economic Research Service using data from the 1997 National Resources Inventory.

Table 4.4
Costs of nitrogen removal by wetlands

Wetland cost		N removal rate = 142 lbs/ac	N removal rate = 214 lbs/ac	N removal rate = 450 lbs/acre	N removal rate = 1,000 lbs/acre
	$/acre	*$/lb of N removed by wetland*			
Marginal cost	77	0.54	0.36	0.17	0.08
Average cost	153	1.08	0.71	0.34	0.15

Note: Because marginal costs are less than average costs, per acre costs would be lower for larger wetlands. N = nitrogen.
Source: USDA, Economic Research Service using data from Mitsch et al., 1999 (142 and 214 pounds per acre) and Crumpton et al., 2008 (450 and 1,000 pounds per acre).

costs to be lower for larger wetlands and potentially more cost effective as a nitrogen filter, all other things being equal.

Wetlands remove most nitrogen through denitrification (Crumpton et al., 2008), which converts nitrate to nitrous oxide (N_2O). However, there is a general belief, supported by a limited number of studies, that N_2O releases are a very small portion of nitrogen removal, even in wetlands with elevated nitrogen loadings (EPA, 2010b). Researchers estimate that N_2O accounts for between 0.13 and 0.30 percent of total annual wetland nitrogen loss (Hernandez and Mitsch, 2006; Crumpton et al., 2008). The reported rates of N_2O releases by wetlands are similar to estimated releases on cropland in the Midwest, so restoring wetlands is likely to have no net effect on N_2O emissions (Crumpton et al., 2008).

Crumpton et al. estimate that nitrogen loads to surface water could be reduced by 30 percent (~500 million pounds) in the Upper Mississippi and Ohio River basins with the addition of 0.5 to 1.1 million acres of strategically placed wetlands, for an average per acre reduction of 450 to 1,000 pounds per year. These removal rates assume an optimal placement of the restored wetlands—areas with a high water flow with high nitrogen concentrations. Mitch et al. (1999) estimate that wetlands in the Midwest remove 142 to 214 pounds per acre of nitrogen per year. The researchers assume that the wetlands are well constructed and placed, but their estimates are based on a wide range of nitrogen concentrations and hydrologic flows. Each study includes multiple wetlands and a variety of flow conditions and nitrogen concentrations.

The unit cost of nitrogen removal by wetlands, based on nitrogen removal rates of 450 to 1,000 pounds per acre per year reported by Crumpton et al. (2008), is $0.08 to $0.34 per pound (table 4.4). Based on the removal rates of 142 to 214 pounds per acre per year reported by Mitch et al. (1999), unit cost ranges from $0.71 to $1.08 per pound.

The Costs of Nitrogen Capture Using Vegetative Filter Strips

Vegetative filter strips present another off-field option for capturing and removing nitrogen from runoff and subsurface waters. The cost of a VFS tends to be lower than the cost of wetlands restoration. The VFS cost has two components: the opportunity cost of holding the land out of production and the cost of establishing cover (e.g., grasses, trees, or both). Cropland rental rates are an economic measure of the opportunity cost of taking cropland out of production. We assume that average cropland rental rates are equal to the economic return to land converted to a VFS. Based on the distribution of corn acreage reported in the 2005 ARMS and county-level rental data provided by NASS, the annual opportunity cost of converting corn cropland into a VFS is estimated at $94 per acre.

We assume that the cost of establishing vegetative cover is about the same as establishing cover on land retired in USDA's Conservation Reserve Program (CRP). CRP data do not specify cost by cover type, but data do provide insights on the range of costs. Across the 25th, 50th, and 75th percentiles, cover costs are $16, $35, and $60 per acre. Because establishing forest cover is more costly, the lower percentile costs likely reflect the cost of establishing grasses.

The cover cost is a one-time investment. We annualized this cost by assuming that it is to last for the foreseeable future and a 5-percent discount rate. Together, the land and cover cost would total approximately $95 to $97 per acre per year, with the higher estimate more likely representative of the use of forest cover.

Mitch et al. (1999) tabulate several plot studies with a focus on the quantity of nitrogen removed across varying sizes of filter strips and levels of nitrogen inflow. They apply their findings to nitrogen runoff rates typical of those in corn-producing areas and estimate that properly designed forested riparian VFS will remove approximately 17.8 to 53.0 pounds of nitrogen per acre with strips ranging in width from 10 to 50 feet (Mitch et al., 1999, pg. 47).

At an annual nitrogen runoff removal rate of 17.8 to 53.0 lbs per acre and a forested VFS cost of $97 per acre, VFS nitrogen removal costs are estimated to range from $1.83 to $5.45 per pound of nitrogen. The cost estimate is a weighted average across the corn-producing areas of the GIP.

Results suggest that, within the GIP, wetlands can be much more cost effective at removing nitrogen than VFS, primarily because of their substantial nitrogen removal rates. Within corn-producing regions, especially in areas where fields are tile drained, water moves quickly through and passes under root zones, rendering VFS ineffective. On the other hand, VFS can be established in many landscape settings where wetlands cannot.

The wide range in nitrogen removal rates by wetlands reflects, at least in part, the advantage of targeting wetlands to areas where they are likely to be more effective—areas where wetlands capture large quantities of water with high nitrogen concentration rates. But even the low nitrogen removal rates of 142 to 214 pounds per acre reported by Mitch et al. are three or more times the removal rates of VFS. Additionally, the rich wetland ecosystems have the potential of providing a greater array of environmental services than those delivered by VFS.

Participation in Emissions Trading Programs

An alternative to publicly provided financial incentives for adoption of conservation practices is for private markets to pay farmers to adopt management practices that produce ecosystem services valued by consumers (the public). Emissions trading uses markets to efficiently achieve pollution targets. The development of markets for ecosystem services is characterized by uncertainties about whether viable markets for public goods can exist, but the EPA and USDA are promoting emissions trading markets for water quality and greenhouse gases as a way of reducing the costs of meeting environmental goals. Agriculture has a potential role to play in both markets.

Water Quality Trading Program

The promise of emissions trading, along with the real-world success of air emissions trading, has led to the creation of water quality trading markets in a number of impaired watersheds. Under the Clean Water Act, point sources (e.g., factories, sewage treatment plants) were initially regulated through a nontradable permit system. A permit specifies how much of a particular pollutant the permit holder can discharge. Traditionally, permit holders were required to meet their permit obligations through their own effluent reductions. EPA policy guidelines on water quality trading now allow point sources to meet their Water Quality Based Effluent Limitation requirements through discharge reductions from other sources under certain conditions, including agricultural nonpoint sources (EPA, 2004). The guidelines encourage States to consider agriculture as a source of offsets in water quality trading programs, and a number of States are either implementing or considering water quality trading programs that allow point/nonpoint source trading. There appears to be many opportunities for point/nonpoint trading programs to be established. Almost 7,000 water bodies impaired by nutrients (pollutants produced by both point and nonpoint sources) have been listed under Section 303(d) of the Clean Water Act (EPA, 2009). To date, over 4,000 Total Maximum Daily Loads (TMDLs) have been developed to address 5,000 of these impaired waters. The presence of a TMDL is a basic requirement for a trading program, as it creates the demand for credits (Ribaudo et al., 2008). Agriculture is a major source of nutrients in most of the watersheds containing impaired waters (Ribaudo and Nickerson, 2009). The marginal cost of reducing nitrogen loss from cropland is generally less than the marginal cost of reducing nitrogen discharges from point sources (primarily sewage treatment plants) (Camacho, 1992; Shortle, 1990).

Forty water quality trading programs have been created in the United States since 1990 (Breetz et al., 2004). Fifteen include production agriculture as a potential source of credits for regulated point sources, most often for nutrients (nitrogen and phosphorus). However, point/nonpoint trading has not been very successful, at least in terms of the participation of potential traders and the number of trades between regulated sources and farms (Breetz et al., 2004).

Regulators designing point/nonpoint trading markets must contend with uncertainty about sources and levels of emissions, the effectiveness of best management practices, the water quality impacts of emissions from different sources, and farmer willingness to participate in a market driven by regulation (on point sources) (Hoag and Hughes-Popp, 1997; King, 2005; King and Kuch, 2003; Woodward and Kaiser, 2002; Ribaudo and Gottlieb, 2011; Horan and Shortle, 2011). The failure of current programs to perform as advertised can largely be attributed to failures of market design and program rules to adequately address these issues, or the high transactions from incorporating uncertainties into market design.

One issue that has particular relevance for addressing nitrogen pollution is the baseline used for calculating credits. The EPA defines a baseline participation requirement as the pollutant control requirements that apply to a seller in the absence of trading (EPA, 2007). EPA suggests that practices generally accepted as good management define a baseline for agriculture, under an assumption that all farms would eventually adopt these practices voluntarily. Some practices that States have used in trading programs to define a baseline include the use of filter strips or a nutrient management plan (Wisconsin DNR, 2002; Pennsylvania DEP, 2008). However, the issue is that our survey data indicate that very few crop acres would meet these baseline requirements as the percentages of cropland with filter strips or nutrient management plans are only 6.8 and 5.0, respectively, meaning that most crop acres would not be able to participate in a trading program until the baseline requirements were met. If the incentives from a credit market are insufficient to induce farms that have not already voluntarily adopted the minimum set of practices to incur the cost of meeting the baseline requirement, then these farms will continue unabated discharge. This entry cost would therefore potentially limit participation and adversely affect the efficiency of the market (Ribaudo and Gottlieb, 2011; Ghosh et al., 2011).

Greenhouse Gas Mitigation

Another emissions market that might influence nitrogen management decisions in agriculture is an offset market for mitigating emissions of CO_2 and other greenhouse gases, such as nitrous oxide (N_2O). Nitrous oxide is a powerful greenhouse gas (310 times the global warming potential of CO_2 over 100 years) and can be emitted from fields receiving nitrogen fertilizer (see chapter 2). A trading program for nitrous oxide emissions would have many of the same design and implementation issues of point/nonpoint trading for water quality. One would expect that the use of models for predicting reductions, based on field and management characteristics, would figure heavily in any trading program.

We use NLEAP results and ARMS cost data to determine changes farmers might make given the opportunity to participate in an offset market for N_2O reductions by producing credits and likely environmental tradeoffs. These analyses were conducted across different management scenarios and general hydrologic soils (e.g., well-drained soils with a large leaching potential versus poorly drained soils with a low leaching potential) from selected counties in Virginia, Ohio, Pennsylvania, and Arkansas.

For each soil, we identified the changes a farmer might make in nitrogen management practices to produce N_2O reductions (offset credits) at the lowest cost while meeting a requirement that total nitrogen emissions (the sum of NO_3, N_2O, and NH_3 losses) not increase. In other words, trading rules do not permit a management change that reduces N_2O but increases total nitrogen emissions. Changes in cost are defined as the difference in average variable costs (chemicals, fuel, and electricity) and value of lost production (changes in yields). We assumed farmers would maintain the same basic cropping system and alter timing, method, or application rate only. A description of

NLEAP and the cost model and assumptions are presented in appendices 2 and 3.

Table 4.5 summarizes the nitrogen management systems that farmers evaluated in the model would adopt to produce credits at the lowest cost, given baseline practices. For example, of the 64 farm types not meeting any of the criteria prior to a market ("None" in the baseline criteria column), 17 would reduce the application rate to the criterion rate, 10 would reduce the rate and inject/incorporate nitrogen, 1 would reduce the rate and apply nitrogen in the spring, and 36 would adopt all three management choices. The choice depends on the soil type, climate, rotation, tillage practice, and nitrogen source.

The results highlight the importance of meeting the application rate criterion for reducing both N_2O and total reactive nitrogen. For all farms not meeting the rate criterion, reducing application rate either alone or in combination with another practices was selected to reduce N_2O. Method or timing was never the sole practice adopted by farms to reduce N_2O emissions. Model results also indicate that 148 of the 512 farming systems will not be able to reduce N_2O emissions by meeting the rate, timing, or method criteria. For example, none of the 64 farm types meeting the rate and method criteria at the start of a market can reduce N_2O emissions by also meeting the timing criterion.

Table 4.6 provides more detail for one soil in Ohio. It shows the reduction in N_2O that would be generated for each decision a farmer in a particular baseline situation could make and credit revenue earned assuming a carbon price of $15 per ton of CO_2 equivalent.[4] The range of N_2O reductions presented here is similar to that found for the other soils modeled with NLEAP.

[4]Based on EPA analysis of the American Clean Energy and Security Act of 2009, H.R. 2454.

Table 4.5

Least-cost N management systems in corn production for reducing N_2O emissions for 512 model farms, assuming a credit price of $15 per ton of CO_2 equivalent, based on NLEAP modeling

Criteria[1] met after changing management	Method	Rate	Timing	Rate and method	Rate and timing	Timing and method	Rate, timing, and method	Total model farms
				Number of model farms				
Criteria[1] met in baseline								
None		17		10	1		36	64
Method		16		17	3		28	64
Rate		19		42			3	64
Timing					63		1	64
Rate and method				64				64
Rate and timing		3		23	1		37	64
Timing and method				31			33	64
Rate, timing, and method							64	64

[1]Criteria are appropriate rate, timing, and method of nitrogen application (see chapter 3).

Note: N = nitrogen. NLEAP = Nitrogen Leaching Environmental Analysis Project. N_2O = nitrous oxide. CO_2 = carbon dioxide. A total of 512 cropping systems are evaluated with NLEAP, 128 each in Arkansas, Ohio, Pennsylvania, and Virginia. Each defines a soil type (A or D), a rotation (continuous corn, corn soybeans), tillage practice (conventional, no-till), nutrient source (inorganic, manure+inorganic), timing of application (before planting, at/after planting), method (inject/incorporate, broadcast) and application rate (meet criterion, 75% over criterion).

Source: USDA, Economic Research Service.

Table 4.6

How a corn farmer may change N management in a market for nitrous oxide (N_2O) greenhouse gas emissions with credit payments of $15/ ton of carbon dioxide equivalent, for a model Ohio farm on Ottoke soil

Baseline practice	Practices after N_2O credit offered	N_2O reduction	Credit revenue
		Pounds per acre	*Dollars per acre*
CC-CON-MF			
M	RTM	0.9	2.09
RM	No change	0.0	0.0
R	RM	0.3	0.70
RTM	No change	0.0	0.0
RT	RM	3.4	7.90
TM	RT	3.0	6.98
T	RT	4.4	10.23
NONE	RTM	0.8	1.86
CC-CON-OF			
M	RTM	0.3	0.70
RM	No change	0	0
R	RM	0.6	1.40
RTM	No change	0	0
RT	RTM	2.7	6.28
TM	RT	0.9	2.09
T	RT	3.1	7.21
NONE	RTM	0.8	1.86
CC-NT-MF			
M	RTM	0.2	0.46
RM	No change	0	0
R	No change	0	0
RTM	No change	0	0
RT	RTM	0.5	1.16
TM	RT	3.3	7.67
T	RT	2.8	6.51
NONE	RM	0.9	2.09
CC-NT-OF			
M	R	1.1	2.58
RM	No change	0	0
R	RM	0.2	0.46
RTM	No change	0	0
RT	RTM	1.7	3.95
TM	RT	1.4	3.26
T	RT	2.8	6.51
NONE	R	0.9	2.09

-- *continued*

Table 4.6

How a corn farmer may change N management in a market for nitrous oxide (N_2O) greenhouse gas emissions with credit payments of $15/ton of carbon dioxide equivalent, for a model Ohio farm on Ottoke soil -- continued

Baseline practice	Practices after N_2O credit offered	N_2O reduction	Credit revenue
		Pounds per acre	*Dollars per acre*
CS-CON-MF			
M	RTM	0.6	1.40
RM	No change	0	0
R	RM	0.2	0.46
RTM	No change	0	0
RT	RM	1.3	3.02
TM	RT	1.6	3.72
T	RT	1.7	3.95
NONE	RTM	0.2	0.46
CS-CON-OF			
M	RTM	0.2	0.46
RM	No change	0	0
R	RM	0.3	0.70
RTM	No change	0	0
RT	RTM	1.2	2.79
TM	RTM	1.1	2.56
T	RT	1.2	2.79
NONE	RTM	0.5	1.16
CS-NT-MF			
M	RT	0.2	0.46
RM	No change	0	0
R	No change	0	0
RTM	No change	0	0
RT	RM	0.8	1.86
TM	RT	1.4	3.26
T	RT	1.4	3.26
NONE	RM	0.5	1.16
CS-NT-OF			
M	R	0.2	0.46
RM	No change	0	0
R	RM	0.2	0.46
RTM	No change	0	0
RT	RTM	1.3	3.02
TM	RTM	1.1	2.56
T	RT	1.4	3.26
NONE	R	0.5	1.16

Note: N = nitrogen. CC = continuous corn, CS = corn-soybeans, CON = conventional till, NT = no-till, MF = manure+inorganic N, OF = inorganic N, M = N incorporated/injected, R = N rate is less than 40% more than N removed at harvest, T = spring application.

Source: USDA, Economic Research Service.

Even though our sample of cropping conditions is very small, we believe we can still make some inferences from the results. We found that if the baseline system is not meeting the application rate criterion, application rate will be reduced to produce credits, either alone or in combination with timing or method; reducing the application rate is generally the most cost-effective means of reducing N_2O emissions. Adopting method and/or timing BMPs alone cannot reduce N_2O emissions or can do so only by reducing overall nitrogen use efficiency, which is not permitted under our simulated market rules.

Farms already meeting both the rate and method criteria will only be able to reduce N_2O emissions by reducing their application rate below recommended rates. The NLEAP modeling indicates only small reductions in N_2O when the application rate is reduced to a level below the criterion rate. This is consistent with field studies that indicate a nonlinear relationship between excessive N application rates and N_2O emissions (Jarecki et al., 2009; McSwiney and Robertson, 2005). Excessive nitrogen inputs accelerate the rate of N_2O emissions. For example, reducing the application rate from the criterion rate to 25 percent below the recommended rate only reduces N_2O by between .2 and 1.3 pounds per acre for the Class A (well-drained) soil in Ohio, depending on the cropping system. Assuming a credit rate of \$15 per ton of CO_2 equivalent, this translates into a payment of between \$0.46 and \$3.02 per acre. These rates are insufficient to cover the 10-percent reduction in corn yields that we assume would occur for such a reduction in N (Bock and Hergert, 1991). Even for smaller N reductions, it is unlikely that revenue from GHG credits would be sufficient to cover the increased risk from cutting N application rates to something close to plant uptake. However, higher offset prices could increase the incentive to cut application rates to reduce N_2O emissions, even when yields might be affected.

When we apply these results to the survey results summarized in table 3.3, we conclude that farmers with treated corn acres meeting the rate, timing, and method criteria or the rate and method criteria (about 42 percent of all corn acres) will not likely participate in a GHG cap-and-trade program that would allow farmers to sell offsets from N_2O reductions. These farms cannot make any management changes to reduce N_2O without reducing overall nitrogen use efficiency, which would violate a market rule. The treatment of such "good stewards" in an emissions trading program is an important policy issue.

The potential revenue from GHG credits produced by reducing N_2O appears to be quite small. In the Ohio example, only a few situations are capable of producing credit revenue of over \$5 per acre, assuming a credit price of \$15 per ton of CO_2 equivalent (and the results are similar for the other States studied). These rates are less than the rates farmers could receive for nutrient management from EQIP, which is a measure of farmers' willingness to accept payment for the practice (table 4.3). In general, farms overapplying nitrogen and broadcasting fertilizer can produce the largest reductions in N_2O. However, only 8.3 percent of corn acres fall in this category (see table 3.3). While we found that changes in operating costs after changing management are near 0 or even negative in most cases, we did not consider short-term adjustment costs, changes in risk, or the administrative costs of participating in an offset program. In the case of farms that also have animals, we did not consider the cost of moving manure produced on the farm to more acres (to reduce application rates), or of moving excess manure off the farm entirely (Ribaudo et al., 2003)—all of which would reduce farmer participation below the rates estimated here.

One issue of concern is the possibility that reducing N_2O could increase nitrate losses to water. As described in chapters 2 and 3, changes in management could change conditions in the soil so that gaseous forms, such as N_2O, are converted to highly soluble nitrate (NO_3). It might seem that allowing only management changes that do not increase total losses of nitrogen would prevent this, but we found otherwise. In 25 percent of the cases where management changes were made to reduce N_2O, NO_3 losses to water increased, even though total nitrogen emissions fell. This occurred almost exclusively when the rate criterion was already being met and injection/incorporation was adopted as an additional practice. While overall N_2O and total nitrogen losses decreased, water quality worsened. Such an outcome would be a concern in regions trying to address water quality problems, such as the Corn Belt, where corn production is the major source of nitrogen contributing to hypoxia in the Gulf of Mexico. Including these factors in the analysis would likely further reduce the net value to society of producing GHG offsets through N_2O emissions reductions.

Response to Price Changes, and What It Means for an Input Tax

Input prices can influence a farmer's planning. For example, low fertilizer prices can lead to "insurance" applications of fertilizer that reduce overall nitrogen use efficiency. Increases in fertilizer prices relative to other input and output prices through the use of an input tax would likely decrease fertilizer use and reduce the number of acres receiving excessive rates. Several States have levied fertilizer taxes in the past but only at low levels that had little impact on use.

The effectiveness of an input tax in reducing excessive application rates would depend largely on the responsiveness of farmers to changes in nitrogen prices. Data from studies spanning several decades reveal that responses to a price change (known as the price elasticity) can vary widely, depending on the data source and time period covered, the type of econometric methods used to analyze the data, the number of crops covered, and the type of crop to which the nitrogen fertilizer is applied. While no true consensus exists, study findings generally show that nitrogen demand was relatively insensitive to price. Burrell (1989) provides a convenient summary of 14 empirical demand studies through the 1980s. Of those 14 studies, only 4 report elasticities greater than unity. Estimates were generally in the range of -0.20 to -0.70, implying that a 10-percent increase in the price of fertilizer reduced demand by 2 to 7 percent (see, for example, Griliches (1958); Carman (1979); Ray (1982); and Shumway (1983)).

Denbaly and Vroomen (1993) use cointegrated and error-corrected models with time series data from 1964 to 1989 to estimate short- and longrun Marshallian elasticities. They report a shortrun Marshallian elasticity of -0.21 and a longrun elasticity of -0.41. Hansen (2004) estimates nitrogen fertilizer demand of farmers in Denmark using an unbalanced panel spanning 1982-91. He concludes that nitrogen demand is similarly insensitive to own-price, with an elasticity of -0.45.

Not all studies found the price elasticity of demand for nitrogen fertilizer to be inelastic. Carman (1979) examines the nitrogen demand in 11 Western States and finds significant State-level variation in elasticities. Statistically significant elasticity estimates in Carman's study range from -0.55 to as large as -1.84. His study shows that demand can vary significantly even within a region. Roberts and Heady (1982) also use annual time-series data from the United States, but spanning 1952-76, and find price elastic demand for nitrogen applied to corn (-1.148). In a study of aggregate fertilizer, Weaver (1983) investigates the demand in just two States, North Dakota and South Dakota, and finds fertilizer demand to be highly elastic, ranging from -1.377 to -2.156.

Some evidence suggests that farmers may be becoming more sensitive to changes in fertilizer prices. Using 2001 and 2005 field-level data from ARMS, we estimate a demand elasticity of nitrogen fertilizer of -1.38 for farmers who applied commercial nitrogen fertilizer to corn (app. 3). Stated another way, if the price of nitrogen fertilizer was to rise by 10 percent, farmers would reduce the amount applied by 13.8 percent. At the mean amount of commercial nitrogen, such a change in price would result in a decrease of 18.2 lbs of fertilizer per acre.[5]

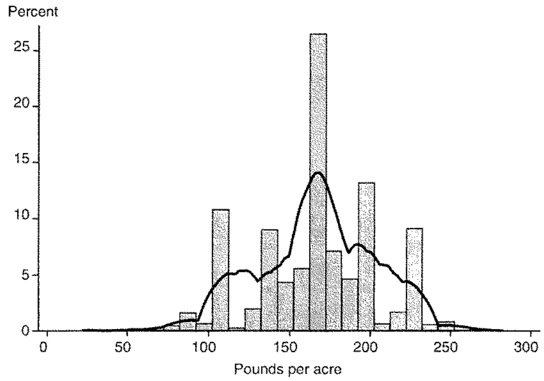
[5]The mean commercial nitrogen application rate in our sample was 129.72 lbs per acre.

Manure can also be used as a source of nitrogen nutrients, usually in conjunction with commercial nitrogen fertilizer. In the ARMS sample, slightly less than a quarter of corn farmers applied manure to the field, and all of them did so in conjunction with commercial nitrogen. When the analysis is expanded to include these farmers, we find a demand elasticity of -0.67; that is, for every 10-percent increase in the price of commercial nitrogen fertilizer, farmers reduce their use of nitrogen (organic and inorganic) by about 7 percent. The results are driven by farmers who use both manure and commercial nitrogen; we find they are relatively less sensitive to the price of commercial nitrogen fertilizer than farmers who apply commercial nitrogen exclusively, which is consistent with the idea that manure and inorganic forms of nutrients are imperfect substitutes. Also, manure management decisions on farms with animals might be driven less by nitrogen prices than by the need to dispose of manure (Ribaudo et al., 2003).

The estimates of price elasticity can be used to provide a rough estimate of the tax that would be needed to reduce application rates so that more acres meet the rate criterion. Figure 4.2 displays the distribution of the nitrogen application rates that represent the criterion rate described in chapter 3. In the case of farmers who used commercial nitrogen exclusively, we have estimated an average criterion application rate at 170.8 lbs per acre for production year 2005. Thirty-five percent of the 76 million corn acres treated with nitrogen exceeded their criterion rate (26.7 million acres), and farmers who exceeded their criterion rate had a mean rate of 185.5 pounds per acre. From the distribution depicted in figure 4.3, the concentration of farmers near zero indicates that most of the farmers who applied nitrogen at rates above the criterion rate are situated near the threshold (also seen in table 3.3). In

Figure 4.2

Distribution of criterion rates[1] for corn, based on reported expected yield, 2005



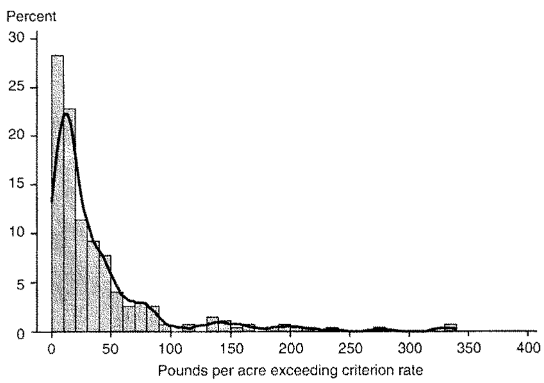
[1]Criterion rate defined as nitrogen removed at harvest plus 40 percent, based on the farmer-stated yield goal.

Note: The kernel density, represented by the smooth line, is an estimate of the continuous density using an Epanechnikov kernel.

Source: USDA, Economic Research Service using USDA's 2005 Agricultural Resource Management Survey.

Figure 4.3

Distribution of nitrogen fertilizer applied to corn that exceeded the criterion rate,[1] 2005



[1]Criterion rate defined as nitrogen removed at harvest plus 40 percent, based on the farmer-stated yield goal.

Note: The kernel density, represented by the smooth line, is an estimate of the continuous density using an Epanechnikov kernel.

Source: USDA, Economic Research Service using USDA's 2005 Agricultural Resource Management Survey.

fact, 50 percent of farmers who exceeded the criterion rate exceeded it by 19 pounds per acre or less.

Table 4.7 provides a summary of the input tax needed to reduce the excess use of nitrogen by farmers who exceed their criterion rate, evaluated for differing levels of demand elasticity. From the table it is evident that the more elastic the demand, the less the price must change to reduce excessive application rates. A highly inelastic demand for nitrogen, for example -0.20, would require more than a 50-percent increase in the price to achieve a 50-percent reduction in excess application. To achieve a reduction of 75 percent, the price would have to more than double.

Based on our estimated elasticity of -1.38, if an input tax increased the price of nitrogen by 7.4 percent, 50 percent (about 13.4 million acres) of the 26.7 million overtreated acres would then meet the rate criterion. Seventy-five percent of heavy nitrogen users exceed the criterion rate by 43.4 pounds per acre or less; thus, raising the price of nitrogen by 17 percent would reduce cropland exceeding the criterion rate by 20 million acres. For context, consider the mean price of nitrogen fertilizer in 2005 was 33 cents per pound; therefore, a 7.4-percent change in the price equates to slightly more than 2.4 cents per pound, and a 17-percent change equates to less than 6 cents per lb.

As a policy instrument, a tax on inputs has some desirable characteristics as well as some well-known drawbacks. First, a tax gives farmers flexibility in how they reduce emissions. Farmers face heterogeneous costs, and a tax enables farmers to tailor their input responses (nitrogen abatement) accordingly (Ribaudo et al., 1999). In the case of nitrogen, an input tax directly affects the farmer's decision that has the largest impact on nitrogen losses to the environment. It would also encourage a farmer to manage nitrogen more carefully, which could lead to appropriate timing and method of application. A tax does not require monitoring or enforcement, unlike a regulation. It can also be easily adjusted if policy goals are not met or exceeded. Another advantage of an input tax is that it raises revenue while reducing application rates. The revenue could be used to reduce the tax burden of crop producers through a system of lump-sum rebates to those producers who improve

Table 4.7

Fertilizer price increases needed to reduce excess nitrogen† applications by 50 percent and 75 percent

Elasticity of nitrogen fertilizer demand	Reduce excess nitrogen application by: 50 percent		75 percent	
	Necessary price change	Tax	Necessary price change	Tax
	Percent	*Dollars*	*Percent*	*Dollars*
-0.20	51.2	0.169	117.0	0.386
-0.50	20.5	0.068	46.0	0.154
-0.70	14.6	0.048	33.4	0.110
-1.00	10.2	0.034	23.4	0.077
-1.38	7.4	0.024	17.0	0.056

Note: † Excess nitrogen application is defined as rate exceeding 40 percent more than nitrogen removed at harvest (see chapter 3).

Source: USDA, Economic Research Service.

nitrogen use efficiency. Revenue can also be used to remedy damages caused by nitrogen losses.

A tax on an input also has drawbacks. An input tax makes no distinction between whether fertilizer is in excess or not. A tax on nitrogen may also encourage increased use of untaxed manure, resulting in no discernable change in nitrogen applications where manure is readily available.

The question of who bears the burden of the tax, also known as the incidence, can have notable distributional consequences. Statutorily, the incidence of the tax could fall on the wholesaler or retailer of nitrogen fertilizer; however, the true, or economic, incidence is likely to be shared with the farmer. How much so is an empirical question that relies on the relative sensitivity of farmers to the price change, as well as the elasticity of the supply of nitrogen: the more sensitive a farmer's demand for nitrogen is, the less of a burden he or she will bear, all else equal. The supply of nitrogen fertilizer is projected to more than meet the demand over the near term; therefore, the standard assumption is that the burden of the excise tax would be considerably shifted to the consumer of the good, in this case the farmer (Fullerton and Metcalf, 2002; FAO, 2008). While corn production in the United States accounts for 39 percent of the world's total corn production, the ability of U.S. farmers to pass along the cost of the tax will depend on the relative elasticities of supply and demand for corn (USDA, FSA, 2011). While a factor tax on nitrogen may improve welfare from society's point of view, ultimately, the tax will change the functional distribution of income. The distributional impact may be mitigated if revenues raised by the tax are returned to the farmer in some manner, for example, by supporting other conservation activities.

Nitrogen Compliance

Compliance provisions require farmers to meet some minimum standard of environmental protection on environmentally sensitive land as a condition for eligibility for many Federal farm program benefits, including conservation and commodity program payments. Under current compliance requirements, farm program eligibility could be denied to producers who:

- Fail to implement and maintain an NRCS-approved soil conservation system on highly erodible land (HEL) (Conservation compliance)
- Convert HEL grasslands to crop production without applying an approved soil conservation system (Sodbuster)
- Convert a wetland to crop production (Swampbuster)

Evidence suggests that the current compliance provisions have contributed to a reduction in soil erosion and discouraged the conversions of noncropped HEL land and wetlands to cropland (Claassen et al., 2004). A possible extension of the provisions could include nutrient management.

Crop producers are a major source of nitrogen. Assessments of the potential efficacy of compliance must consider two key questions:

- To what extent do crop producers who have the greatest potential for reducing nitrogen emissions also participate in farm programs?

- Are Government payments to these producers large enough to encourage broad adoption of practices that improve nitrogen use efficiency and reduce nitrogen emissions?

Claassen et al. (2004) estimate that 75 percent or more of cropland acres with medium, high, or very high potential for nitrogen leaching or runoff are located on farms that receive Government payments. We used data from the 2005 ARMS corn survey to estimate Government payments received by corn producers.[6] We looked at all treated corn acres, as compliance provides an incentive both for farmers already practicing good nitrogen management and willing to continue and for farmers not using nitrogen BMPs and willing to adopt them. Over 97 percent of corn acres receive Government payments, averaging $51.39 per acre. This average is higher than our estimated costs of improving NUE or of adopting NRCS practices. Eighty-eight percent of treated corn acres receive Government payments in excess of $27 per acre per year, which is more than the average EQIP payments for nutrient management or waste use. (Note that for corn acres that are highly erodible and subject to conservation compliance, it is the sum of erosion control and nitrogen management costs that would be considered by the farmer.)

[6]The ARMS data do not enable us to identify only those program payments subject to compliance, but they are a good approximation.

A drawback of compliance is that the strength of the incentive is dependent on the level of Government payments. Current events present a good example. Direct Government payments have been reduced by about 50 percent between 2005 and 2009 due to a number of factors, including higher crop prices and smaller disaster payments (USDA, ERS, 2010). Assuming that average per acre payments to corn producers were reduced by the same percentage, the average estimated cost of the more expensive nitrogen management practices, such as waste utilization, would be greater than the program benefit. Compliance would not be an effective tool in this case. The point is that program payments can vary greatly, making compliance an unpredictable policy instrument.

Regulation

Another policy approach for improving NUE is to legally require farms to adopt and implement particular management practices. Such an approach would be a major change in the way most of agriculture is treated under current environmental laws. With few exceptions, agricultural operations are exempt from regulation under the Clean Water Act and Clean Air Act. A number of arguments have been used as justification. First, agriculture is so diverse across the United States that the conventional regulatory approach of applying uniform standards is impractical (Nanda, 2006). Second, due to the nonpoint nature of agricultural pollution, individual polluters cannot be identified except at great cost.

Regulation can conceptually be placed on a continuum between performance standards and design standards (Ribaudo et al., 1999). Performance standards directly regulate emissions. Design standards dictate how producers manage their operations, including practices that should not be used and/or BMPs that should be adopted. Because of the nonpoint nature of agricultural pollution, design standards are the only practical approach for addressing nitrogen losses.

One approach would be to require that farmers adopt specific BMPs to improve their nitrogen use efficiency. Generally, a practice-based regulation is inefficient because it requires producers to adopt the same practice, whether it is appropriate for their particular farm or not. It may be more effective to define BMPs locally so as to allow flexibility and to account for agriculture's heterogeneous nature. For example, a nitrogen management plan is a flexible practice that is based on a farmer's resources and cropping system. However, farmers may fail to implement the plan properly. The effectiveness of a regulation therefore requires effective inspection and enforcement by a resource management agency. Implementation costs would likely be high. Several States, such as Nebraska and Maryland, have required farmers in particularly vulnerable areas to adopt specific nutrient management practices to protect ground or surface water (Ribaudo, 2009).

One of the few segments of the agricultural sector that has been subjected to regulatory environmental measures at the national level is animal feeding operations, reflecting heightened concern over pollution from animal waste from the largest operations (USDA-EPA, 1999). Manure is estimated to be a source of about 17 percent of nitrogen entering U.S. waters (Smith et al., 1997). Clean Water Act regulations now require that animal feeding operations designated as Concentrated Animal Feeding Operations, or CAFOs, and needing a National Pollutant Discharge Elimination System (NPDES) permit (those CAFOs that discharge or propose to discharge to surface waters), develop and implement a nutrient management plan to cover fields that receive manure. Such a plan, which would meet NRCS standards, sets a limit on the amount of nutrients that can be applied per acre of land and specifies erosion control measures to prevent the loss of sediment and nutrients. Also under the new regulations, CAFOs that are not required to have an NPDES permit but that wish to claim the storm water exemption (the provision in the Clean Water Act that exempts field practices from requiring a discharge permit) for runoff from fields must develop and implement a nutrient management plan to demonstrate that due care is being taken to minimize polluted runoff from fields receiving manure. If a waterway becomes polluted with animal waste from field runoff and a CAFO does not have an approved nutrient management plan, this would be a violation of the Clean Water Act. This approach sets a level of expected stewardship, namely the implementation of a nutrient management plan.

Requiring not just CAFOs but all animal feeding operations to adopt nutrient management plans would be costly. ERS estimates that reductions in net returns in the livestock and poultry sector would be about $1.4 billion per year, and national economic welfare for producers and consumers would decline almost $2 billion per year (Ribaudo et al., 2003). The benefit would be improved air and water quality. Targeting the regulatory approach only to those operations most susceptible to pollution problems would lower the overall costs.

Chapter 5

Implications for Nitrogen Management Policies

Nitrogen is critical for producing abundant food and generating high net returns to producers, yet it has wide-ranging environmental impacts across land, water, and the atmosphere. More careful management that reduces environmental losses would address a number of environmental issues, such as hypoxia in coastal estuaries and bays, the potential for global warming, and nutrient enrichment of terrestrial ecosystems. Policymakers have a number of tools at their disposal, each with its own strengths and weaknesses (table 5.1). No one policy approach can be considered "best," and a concerted effort to address the Nation's nitrogen problems will likely require a solution comprising a mix of policies. Our analysis provides some guidance on determining which sectors of agriculture are most in need of improved management, what are the potential pitfalls, and how might the different policies be orchestrated in an overall policy framework.

Reducing Application Rates as a Priority Policy Goal

Reducing the application of nitrogen fertilizers appears to be the most effective BMP for reducing the emission of nitrogen into the environment. Based on the literature, and confirmed by our NLEAP modeling, reducing application rates is the one BMP that reduces *all* forms of reactive nitrogen, even when the timing and method of application are not ideal. Improving timing or method of application alone could increase one type of reactive nitrogen (transmitted to the atmosphere, groundwater, or surface water) while still reducing total nitrogen emissions. Reducing the application rate is therefore conducive to an ecosystem approach to management that provides protection to all ecosystem services and functions. Improving rate, timing, and method of nitrogen application would produce the greatest environmental benefits.

Reducing application rates that are agronomically excessive may increase the perceived risk of reduced yields. Farmers often use nitrogen fertilizer to manage the downside risk due to uncertain weather and soil nitrogen. Research on how farmers view risk and how they might respond to an incentive payment for reducing application rates, coupled with the use of a risk management instrument, could result in the development of a more effective approach for reducing nitrogen in the environment. Revenue or yield insurance policies could be offered to protect the income of farmers who adopt conservation measures that improve nitrogen use efficiency but may decrease yields because of nitrogen insufficiency stemming from unfavorable weather conditions. Findings from other studies suggest that insurance will likely lead to reductions in nitrogen fertilizer applications, but by how much is uncertain (see Babcock and Hennessy, 1996; Mishra et al., 2005; Smith and Goodwin, 1996).

Table 5.1
Summary of policy instruments for improving nitrogen use efficiency

	Policy instrument					
Characteristics	Input tax	Information	Financial incentives	Compliance	Emissions market	Regulation
Strength of incentive	Depends on level of tax and price elasticity of demand.	A farmer will take action only if management practice improves profits.	Depends on level of subsidy.	Depends on level of Government program payments subject to compliance.	Depends on level of demand from regulated sectors.	Strong.
Acres covered	Covers all acres that are treated with commercial nitrogen.	No guarantee that acres in need of treatment will be addressed.	No guarantee that acres most in need of treatment will be addressed.	May not cover all acres.	May be limited by geographic scope of market and baseline rules.	Can cover all acres that use commercial nitrogen or animal waste.
Targets problem	Directly addresses application rate, but not timing and method. Also, does not address application of animal waste.	Information can be targeted to specific problems.	Incentives can be targeted to specific practices and regions. However, important to consider potential environmental tradeoffs.	Strength of incentive may not be correlated with acres most in need of treatment.	Generally limited to one pollutant and not overall nitrogen use efficiency. Environmental tradeoffs a potential problem.	Can target all aspects of nutrient management. However, important to consider potential environmental tradeoffs.
Flexibility	Very flexible – farmers can adjust in the most cost effective way.	Flexible – farmers act on information that is beneficial to them.	Practice-based incentives are less flexible than incentives on environmental performance.	Flexibility depends on how provisions are defined.	Can be flexible, but depends on market rules.	Limited flexibility, as regulations generally require specific practices.
Implementation costs	Easy to implement, and generates revenues that can be used to reduce economic impacts for farmers who make improvements.	Requires research and extension outreach.	High costs to taxpayers.	Enforcement costs may be high.	Transactions costs can be very high.	Enforcement costs can be high.

Corn Is the Most Important Crop for Addressing Nitrogen-Related Environmental Issues

Corn is the most widely planted crop in the United States and the most intensive user of nitrogen. In 2006, corn accounted for an estimated 65 percent of the total quantity of nitrogen applied to major U.S. field crops. Corn also accounted for half of all nitrogen-treated crop acres that were not meeting the rate, timing, or method of application criteria used in this analysis to define acceptable nitrogen management. Land used to grow corn accounted for the largest share of treated acres that had tile drainage in 2006. Although tile drains improve yields, they also increase the amount of nitrogen that is lost to surface water. Tiled corn cropland not meeting all three nitrogen management criteria would be a prime target for policies for improving nitrogen use efficiency.

In addition, recent demand pressures due to the biofuels mandate, as well as increasing international demand for feed grains, suggests that corn acreage and the intensity of corn production are likely to increase. Together, these factors increase the importance of raising the NUE in corn production in the United States, especially on farms that raise livestock and apply manure to their fields.

Which Policy Is Best?

This analysis provides some guidance on how different policies might be orchestrated in an overall policy framework. The current approach to improving nutrient management on cropland has relied primarily on financial incentives and information. While years of financial and technical assistance have resulted in some progress, operators of over 65 percent of U.S. cropland are still not implementing nitrogen BMPs. Higher payment rates would encourage more producers to adopt practices that improve nitrogen use efficiency, but the cost to taxpayers may be substantial. The level of financial assistance that would be required to entice all farmers with cropland acres needing improved management to enroll in a program would likely consume most of the budget for EQIP. While nitrogen management is an important conservation goal, EQIP and other USDA conservation programs address a host of other issues. Any elevation of nitrogen management as a priority for EQIP may result in fewer resources for other conservation issues.

Emissions markets, such as those for water quality or greenhouse gases, could be a source of financial support for improving nitrogen use efficiency. Markets for agricultural offsets shift the financial burden away from taxpayers to regulated sectors of the economy. While emissions markets are receiving much interest in efforts to improve water quality and to reduce greenhouse gas emissions, their role in improving nutrient management on all acres needing improvement is probably limited. Emissions markets generally target particular geographic areas or particular practices, potentially limiting the number of acres that might be affected. Market rules designed to ensure the "additionality" of offsets by setting baselines consistent with a high level of management may limit participation by farmers not using BMPs, even though a market would benefit by their participation. In addition, the nonpoint source nature of nitrogen emissions from agriculture greatly complicates the design of markets and raises transactions costs.

If voluntary financial assistance programs or emissions markets are limited in their ability to improve nitrogen management across all crop acres, what other approaches might achieve improved nitrogen use efficiency at least cost? The alternative approaches all result in increased costs for farmers. In theory, cost-effective policy instruments target the problem, are flexible, are easy to implement (low transactions costs), and limit costs to both farmers and Government. A tax on nitrogen fertilizer would provide an incentive to all users to manage commercial nitrogen more carefully. If farmers are responsive to price, then this instrument may be an effective means of reducing nitrogen losses. Our assessment of farmer price responsiveness indicates that a relatively low tax may pay high environmental dividends. However, if farmers are as unresponsive to nitrogen prices as generally reported in the literature, a substantially higher tax would be necessary to obtain the same environmental benefits. The burden on farmers would be substantial. Another drawback of an input tax is that a tax would also be paid on applications that are not excessive. A tax only on emissions would be far more efficient, but such a tax is not practical since emissions cannot be observed or easily measured. Finally, some means of addressing the application of animal waste would have to be found, as a fertilizer tax would likely encourage the substitution of manure for commercial nitrogen.

A nutrient management plan is an inherently flexible management practice that is strongly encouraged by USDA but only required for animal feeding operations that are designated as CAFOs. Requiring that all users of nitrogen inputs (commercial and manure) develop and implement a nutrient management plan would be a major change in the way the environmental performance of agriculture is managed. The costs to crop farmers of implementing a nutrient management plan may not be high, except for those managing large amounts of manure produced on the farm. However, many aspects of a nutrient management plan, such as application rate, are difficult to observe, making enforcement difficult and costly.

Enforcement costs could also be high for a compliance approach to getting farmers to adopt nutrient management plans. The effectiveness of compliance would depend on the level of program payments received by farmers and a coincidence of the incentive with those crop acres most in need of improved management. A large share of crop acres in need of treatment receives high levels of Government program payments. While the incentive level in 2005 was quite high, program payments have declined in recent years as crop prices have risen. Continued high prices and general concerns about Federal budget outlays may limit the strength of a compliance-type policy instrument unless it is linked to a broader suite of payments than current compliance requirements.

Improving nitrogen use efficiency reduces the amount of emissions from cropland but does not eliminate them. In areas where even small levels of emissions could cause environmental problems, offsite filtering could supplement onfield management. The Government currently provides financial incentives for creating and preserving wetlands and vegetative filter strips. Though funds are not allocated solely for nitrogen capture and removal, there may be reasons to do so. An economic comparison of the two types of filters suggests that wetlands can be much more cost effective at removing nitrogen than filter strips. While our analysis found that the cost of establishing a wetland is greater than the cost of establishing filter strips, annual nitrogen removal rates are several times greater for wetlands. Filter strips may also be rendered ineffective where tile drains are present, while wetlands can be strategically positioned in the landscape to filter drainage coming from tiled fields. Wetlands also produce a number of other desirable ecosystem services, such as wildlife habitat. Filter strips, however, can be established in landscape settings where wetlands cannot. The choice will depend on geography, soil, and hydrologic conditions.

While one single policy instrument does not emerge as a clearly superior approach to improving NUE across all cropland, a role can be seen for each. Financial assistance could be made available to those producers wanting to voluntarily improve nutrient management and to install vegetative filters or resore wetlands. Since commodity programs are important to farmers, compliance can provide some incentive for those receiving program payments. The level of incentive may vary from year to year, but it may be effective for some farmers. Finally, in regions where nitrogen-related pollution is of particular concern, such as the Chesapeake Bay watershed and the watersheds contributing nitrogen to the Gulf of Mexico, a regulatory backstop could be a measure of last resort for those unwilling to voluntarily adopt nitrogen BMPs.

Information Supports All Policies

Information about the environmental and economic performance of improved nitrogen management practices supports all policies aimed at improving NUE. Reliable, timely information on soil and plant nitrogen reduces one source of uncertainty that tends to encourage overapplication of nitrogen. Our research supports previous findings that testing for nitrogen available in the soil and contained in crops may result in lower application rates. Information from testing can be incorporated into an adaptive management framework, where a farmer evaluates his practices from the previous year (or even at the start of the current growing season) to assess what options may be available to improve nutrient management while sustaining yields and reducing nutrient losses to the environment. So, whether farmers are considering best nitrogen management practices due to regulation, taxes, or financial incentives, information on how to conduct and interpret nitrogen tests and how to successfully implement new practices can reduce the overall costs and increase adoption rates.

Potential Tradeoffs Are an Important Consideration

Reactive nitrogen is easily converted to forms that are readily transported by hydrologic and atmospheric processes. Therefore, focusing strictly on one issue, such as nitrate leaching, could lead to increased emissions of other nitrogen compounds, such as nitrous oxide to the atmosphere, if nitrogen's characteristics are ignored. Even when total nitrogen emissions are reduced by a policy, emissions of one or more nitrogen compounds might increase and degrade environmental quality. This effect was predicted in the case of the market for nitrous oxide offsets—farmers reduced total emissions but increased nitrogen losses to water. These tradeoffs often depend on soils and cropping practices, so it is difficult to develop general "rules of thumb," other than recommending that a holistic approach to management that considers potential environmental tradeoffs be adopted. Reducing nitrogen application rates is the easiest and most effective way to reduce all forms of reactive nitrogen.

References

Abt Associates. 2000. *Air Quality Impacts of Livestock Waste*. Report prepared for U.S. Environmental Protection Agency, Office of Policy.

Alley, M.M., M.E. Martz, Jr., P.H. Davis, and J.L. Hammons. 2009. *Nitrogen and Phosphorus Fertilization of Corn*. Publ. 424-027. Virginia Cooperative Ext., Virginia Polytechnic Institute and State University. (Available online at www.pubs.ext.vt.edu/424/424-027/424-027.html.) (Verified June 3, 2010.)

Alva, A.K., S. Paramasivam, K. Sajwan, A. Fares, J.A. Delgado, and D. Mattos. 2005. "Nitrogen and Irrigation Management Practices To Improve Nitrogen Uptake Efficiency and Minimize Leaching," *Journal of Crop Improvement* 15(2):369-420.

Angier, J.T., G.W. McCarty, T.J. Gish, and C.S. Daughtry. 2001. "Impact of a First-Order Riparian Zone on Nitrogen Removal and Export From an Agricultural Ecosystem," *TheScientific World* 1(Suppl 2):642-651.

Babcock, B.A. 1992. "The Effects of Uncertainty on Optimal Nitrogen Applications," *Review of Agricultural Economics* 14(2):271-280.

Babcock, B.A., and A.M. Blackmer. 1992. "The Value of Reducing Temporal Input Nonuniformities," *Journal of Agricultural and Resource Economics* 17:355-347.

Baker, J. 2001. "Limitations of Improved Nitrogen Management to Reduce Nitrate Leaching and Increase Use Efficiency," in Optimizing Nitrogen Management in Food and Energy Production and Environmental Protection: Proceedings of the 2nd International Nitrogen Conference on Science and Policy, *TheScientificWorld* 1(S2):10-16.

Bausch, W.C., and J.A. Delgado. 2003. "Ground-Based Sensing of Plant Nitrogen Status in Irrigated Corn To Improve Nitrogen Management," in T. Van Toai, D. Major, M. McDonald, J. Schepers, and L. Tarpley (eds.), *Digital Imaging and Spectral Techniques: Applications to Precision Agriculture and Crop Physiology*, ASA Spec. Publ. 66, American Society of Agronomy, Crop Science Society of America, Soil Science Society of America. pp. 151-163.

Beckie, H.J., A.P. Moulin, C.A. Campbell, and S.A. Brandt. 1995. "Testing Effectiveness of Four Simulation Models for Estimating Nitrates and Water in Two Soils," *Canadian Journal of Soil Sciences* 75(1):135-143.

Beegle, D.B., and P.T. Durst. 2003. *Nitrogen Fertilization of Corn*, Agronomy Facts 12, College of Agricultural Sciences Cooperative Extension, The Pennsylvania State University. (Available online at http://export.nbii.gov/xml/web-resources/xmlfiles)

Bishop, C.P., C.R. Shumway, and P.R. Wandschneider. 2010. "Agent Heterogeneity in Adoption of Anaerobic Digestion Technology: Integrating Economic, Diffusion, and Behavioral Innovation Theories," *Land Economics* 86(5):585-608.

Bock, B.R., and W. Hergert. 1991. "Fertilizer Nitrogen Management," in H. Follet et al. (eds.), *Managing Nitrogen for Groundwater Quality and Farm Profitability*, Soil Science Society of America, pp. 140-164.

Bosch, D.J., Z.L. Cook, and K.O. Fuglie. 1995. "Voluntary Versus Mandatory Agricultural Policies To Protect Water Quality: Adoption of Nitrogen Testing in Nebraska," *Review of Agricultural Economics* 17:13-24.

Breetz, H.L., K. Fisher-Vander, L. Garzon, H. Jacops, K. Kroetz, and R. Terry. 2004. *Water Quality Trading and Offset Initiatives in the U.S.: A Comprehensive Survey*. Dartmouth College. (Available online at http://www.dartmouth.edu/~kfv/waterqualitytradingdatabase.pdf)

Bricker, S., B. Longstaff, W. Dennison, A. Jones, K. Boicourt, C. Wicks, and J. Woerner. 2007. *Effects of Nutrient Enrichment in the Nation's Estuaries: A Decade of Change*. NOAA Coastal Ocean Program Decision Analysis Series No. 26, National Centers for Coastal Ocean Science.

Burrell, A. 1989. "The Demand for Fertilizer in the United Kingdom," *Journal of Agricultural Economics* 40:1-20.

Camacho, R. 1992. *Chesapeake Bay Program Nutrient Reduction Strategy Reevaluation. Financial Cost Effectiveness of Point and Nonpoint Source Nutrient Reduction Technologies in the Chesapeake Bay Basin*, Interstate Commission on the Potomac River Basin Report No. 92-4.

Carman, H.F. 1979. "The Demand for Nitrogen, Phosphorous, and Potash Fertilizer Nutrients in the Western United States," *Western Journal of Agricultural Economics* 4(1):23-32.

Cassman, K.G., A. Dobermann, and D.T. Walters. 2002. "Agroecosystems, Nitrogen-Use Efficiency, and Nitrogen Management," *Ambio* 31(2):132-140.

Chouinard, H.H., T. Paterson, P.R. Wandschneider, and A.M. Ohler. 2008. "Will Farmers Trade Profits for Stewardship? Heterogeneous Motivations for Farm Practice Selection," *Land Economics* 84 (1): 66-82.

Claassen, R., V. Breneman, S. Bucholtz, A. Cattaneo, R. Johansson, and M. Morehart. 2004. *Environmental Compliance in U.S. Agricultural Policy: Past Performance and Future Potential*, Agricultural Economic Report No. 832, U.S. Department of Agriculture, Economic Research Service. (Available online at www.ers.usda.gov/publications/aer832)

Cooper, J.C., and R.W. Keim. 1996. "Payments To Encourage Farmer Adoption of Water Quality Protection Practices," *American Journal of Agricultural Economics* 78(1): 54-64.

Cowling, E., J. Galloway, C. Furiness, and J.W. Erisman et al. 2002. "Optimizing Nitrogen Management and Energy Production and Environmental Protection." Presented at the Second International Nitrogen Conference. Bolger Center, Potomac, MD, October 14-18, 2001. (Available at www.initrogen.org/fileadmin/user_upload/Second_N_Conf_Report.pdf. (Verified May 10, 2010).

Crumpton, W. G., D. A. Kovacic, D.L. Hey, and J.A. Kostel. 2008. "Potential of Restored and Constructed Wetlands To Reduce Nutrient Export From Agricultural Watershed in the Corn Belt," in Final Report: Gulf Hypoxia and Local Water Quality Concerns Workshop, American Society of Agricultural and Biological Engineers.

Crutchfield, S.R., P.M. Feather, and D.R. Hellerstein. 1995. *The Benefits of Protecting Rural Water Quality: An Empirical Analysis*. Agricultural Economic Report No. 701, U.S. Department of Agriculture, Economic Research Service, January. (Available online at www.ers.usda.gov/publications/aer701)

David, M.B., L.E. Drinkwater, and G.E. McIsaac. 2010. "Sources of Nitrate Yields in the Mississippi River Basin," *Journal of Environmental Quality* 39;1657-1667.

Davis, J.G., K.V. Iversen, and M.F. Vigil. 2002. "Nutrient Variability in Manures: Implications for Sampling and Regional Database Creation," *Journal of Soil and Water Conservation* 57:473-478.

Delgado, J.A. 2001. "Use of Simulations for Evaluation of Best Management Practices on Irrigated Cropping Systems," pp. 355-381, in M.J. Shaffer, L. Ma, and S. Hansen (eds.), *Modeling Carbon and Nitrogen Dynamics for Soil Management*, Boca Raton, FL: Lewis Publishers.

Delgado, J.A., and M.J. Shaffer. 2008. "Nitrogen Management Modeling Techniques: Assessing Cropping Systems/Landscape Combinations," p. 539-570, in R.F. Follett and J.L. Hatfield (eds.), *Nitrogen in the Environment: Sources, Problems and Management*. New York: Elsevier Science.

Delgado, J.A., and W. Bausch. 2005. "Potential Use of Precision Conservation Techniques To Reduce Nitrate Leaching in Irrigated Crops," *Journal of Soil and Water Conservation* 60:379-387.

Delgado, J.A., A.R. Mosier, R.H. Follett, R.F. Follett, D.G. Westfall, L.K. Klemedtsson, and J. Vermeulen. 1996. "Effects of N Management on N_2O and CH_4 Fluxes and ^{15}N Recovery," *Nutrient Cycling in Agroecosystems* 46:127-134.

Delgado, J.A., C.M. Gross, H. Lal, H. Cover, P. Gagliardi, S.P. McKinney, E. Hesketh, and M.J. Shaffer. 2010a. "A New GIS Nitrogen Trading Tool Concept for Conservation and Reduction of Reactive Nitrogen Losses to the Environment," *Advances in Agronomy* 105:117-171.

Delgado, J.A., M. Shaffer, C. Hu, R. Lavado, J. Cueto-Wong, P. Joosse, D. Sotomayor, W. Colon, R. Follett, S. DelGrosso, X. Li, and H. Rimski-Korsavok. 2008a. "An Index Approach to Assess Nitrogen Losses to the Environment," *Ecological Engineering* 32:108–120.

Delgado, J.A., M.J. Shaffer, H. Lal, S.P. McKinney, C.M. Gross, and H. Cover. 2008b. "Assessment of Nitrogen Losses to the Environment With a Nitrogen Trading Tool (NTT)," *Computers and Electronics in Agriculture* 63:193-206.

Delgado, J.A., R. Khosla, W.C. Bausch, D.G. Westfall, and D. Inman. 2005. "Nitrogen Fertilizer Management Based on Site-Specific Management Zones Reduce Potential for NO_3-N Leaching," *Journal of Soil and Water Conservation* 60:402–410.

Delgado, J.A., R.F. Follett, and M.J. Shaffer. 2000. "Simulation of NO_3-N Dynamics for Cropping Systems With Different Rooting Depths," *Soil Science Society of America Journal* 64:1050-1054.

Delgado, J.A., R. Ristau, M.A. Dillon, H.R. Duke, A. Stuebe, R.F. Follett, M.J. Shaffer, R.R. Riggenbach, R.T. Sparks, A. Thompson, L.M. Kawanabe, A. Kunugi et al. 2001. "Use of Innovative Tools To Increase Nitrogen Use Efficiency and Protect Environmental Quality in Crop Rotations," *Communications in Soil Science and Plant Analysis* 32:1321-1354.

Delgado, J.A., S.J. Del Grosso, and S.M. Ogle. 2010b. "^{15}N Isotopic Crop Residue Cycling Studies and Modeling Suggest That IPCC Methodologies To Assess Residue Contributions to N_2O-N Emissions Should Be Reevaluated," *Nutrient Cycling in Agroecosystems* 86:383–390.

Denbaly, M., and H. Vroomen. 1993. "Dynamic Fertilizer Nutrient Demands for Corn: A Cointegrated and Error-Correcting System," *American Journal of Agricultural Economics* 75(1): 203-209.

Dobermann, A., R. Ferguson, G. Hergert, C. Shapiro, D. Tarkalson, D.T. Walters, and C. Wortmann. 2006. "Nitrogen Response in High-Yielding Corn Systems of Nebraska," in Proceedings of the Great Plains Soil Fertility Conference, Denver, CO, March 7-8, Vol. 11, pp. 50-59, Potash and Phosphate Institute, Brookings, SD.

Dodds, W.K., W.W. Bouska, J.L. Eitzmann, T.J. Pilger, K.L. Pitts, A.J. Riley, J.T. Schloesser, and D.J. Thornbrugh. 2009. "Eutrophication of U.S. Freshwaters: Analysis of Potential Economic Damages," *Environmental Science and Technology* 43(1):12-19.

Doerge, T.A., R.L. Roth, B.R. Gardner (eds.). 1991. *Nitrogen Fertilizer Management in Arizona*, University of Arizona, College of Agriculture.

Dosskey, M.G., D.E. Eisenhauer, and M.J. Helmers. 2005. "Establishing Conservation Buffers Using Precision Information," *Journal of Soil and Water Conservation* 62:349-354.

Dosskey, M.G., M.J. Helmers, and D.E. Eisenhauer. 2007. "An Approach for Using Soil Surveys To Guide the Placement of Water Quality Buffers," *Journal of Soil and Water Conservation* 61:344-354.

Drury, C.F., W.D. Reynolds, C.S. Tan, T.W. Welacky, W. Calder, and N.B. McLaughlin. 2006. "Emissions of Nitrous Oxide and Carbon Dioxide: Influence of Tillage Type and Nitrogen Placement Depth," *Soil Science Society of America Journal* 70(2):570-581.

Dubrovsky, N.M., K.R. Burow, G.M. Clark, J.A.M. Gronberg, P.A. Hamilton, K.J. Hitt, D.K. Mueller, M.D. Munn, L.J. Puckett, B.T. Nolan, M.G. Rupert, T.M. Short, N.E. Spahr, L.A. Sprague, and W. G. Wilbur. 2010. *The Quality of Our Nation's Waters - Nutrients in the Nation's Streams and Groundwater, 1992-2004*. Circular-1350. U.S. Geological Survey.

Eghball, B., B.J. Wienhold, J.E. Gilley, and R.A. Eigenberg. 2002. "Mineralization of Manure Nutrients," *Journal of Soil and Water Conservation* 57:470-473.

Espinoza, L., and J. Ross. 2008. "Fertilization and Liming," pp. 23-27, in L. Espinoza and J. Ross (eds.), *Corn Production Handbook*. Cooperative Extension Service, University of Arkansas, Little Rock, AR. (Available online at www.uaex.edu/Other_Areas/ publications/HTML/MP-437.asp.) (Verified June 3, 2010.)

Flessa, H., and F. Beese. 2000. "Laboratory Estimates of Trace Gas Emissions Following Surface Application and Injection of Cattle Slurry," *Journal of Environmental Quality* 29: 262-268.

Follett, J.R., R.F. Follett, and W.C. Herz. 2010. "Environmental and Human Impacts of Reactive Nitrogen," in J.A. Delgado and R.F. Follett (eds.), *Advances in Nitrogen Management for Water Quality*, Soil and Water Conservation Society.

Food and Agriculture Organization of the United Nations (FAO). 2008. *Current World Fertilizer Trends and Outlook to 2012*, Rome.

Fox, R.H., W.P. Piekielek, and K.E. Macneal. 1996. "Estimating Ammonia Volatilization Losses From Urea Fertilizers Using a Simplified Micrometerological Sampler," *Soil Science Society of America Journal* 60:596-601.

Freney, J.R., J.R. Simpson, and O.T. Denmead. 1981. "Ammonia Volatilization," *Ecological Bulletin* 33:291-302.

Freney, J.R., M.B. Peoples, and A.R. Mosier. 1995. *Efficient Use of Fertilizer Nitrogen by Crops*, Extension Bulletin 414, Food & Fertilizer Technology Center, Taipei, Taiwan. (Available online at www.agnet.org/library/ eb/414) (Accessed December 29, 2009.)

Fullerton, D., and G.E. Metcalf. 2002. "Chapter 26 Tax Incidence," *Handbook of Public Economics* 4:1787-1872.

Galloway, J.N., A.R. Townsend, J.W. Erisman, M. Bekunda, Z. Cai, J.R. Freney, L.A. Martinelli, S.P. Seitzinger, and M.A. Suttan. 2008. "Transformation of the Nitrogen Cycle: Recent Trends, Questions, and Potential Solutions," *Science 320*(May 16):889-892.

Galloway, J.N., J.D. Aber, J.W. Erisman, S.P. Seitzinger, R.W. Howarth, E.B. Cowling, and B.J. Cosby, 2003, "The Nitrogen Cascade," *BioScience* 53(4): 341-356.

Ghosh, G., Ribaudo, M., and J. Shortle. 2011. "Do Baseline Requirements Hinder Trades in Water Quality Trading Programs?" *Journal of Environmental Management* 92(8):2076-2084.

Gollehon, N., M. Caswell, M. Ribaudo, R. Kellogg, C. Lander, and D. Letson. 2001. *Confined Animal Production and Manure Nutrients.* Agricultural Information Bulletin No. 771, U.S. Department of Agriculture, Economic Research Service. (Available online at www.ers.usda.gov/publications/aib771/)

Goolsby, D.A., W.A. Battaglin, B.T. Aulenbach, and R.P. Hooper. 2001. "Nitrogen Input to the Gulf of Mexico," *Journal of Environmental Quality* 30: 329-336.

Greene, W.H. 2000. *Econometric Analysis, Fourth Edition.* Upper Saddle River, NJ: Prentice Hall.

Griliches, Zvi. 1958. "The Demand for Fertilizer: An Economic Interpretation of a Technological Change," *Journal of Farm Economics* 40(3): 591-606.

Grossman, M.R. 2007. "Agriculture and the Polluter Pays Principle," *Electronic Journal of Comparative Law* 11(3), 1-66.

Hansen, Lars Garn. 2004. "Nitrogen Fertilizer Demand From Danish Crop Farms: Regulatory Implications of Heterogeneity," *Canadian Journal of Agricultural Economics* 52(3): 313-313.

Hefting, M.M., R. Bobbink, and H. de Caluwe. 2003. "Nitrous Oxide Emission and Denitrification in Chronically Nitrate-Loaded Riparian Buffer Zones," *Journal of Environmental Quality* 32:1194-1203.

Henandez, M., and W. Mitsch. 2006. "Influence of Hydrologic Pulses, Fooding Frequency, and Vegetation on Nitrous Oxide Emissions From Created Riparian Marshes," *Wetlands* 26(3): 862-877.

Hernandez-Ramirez, G., S.M. Brouder, D.R. Smith, and G.E. Van Scoyoc. 2009. "Greenhouse Gas Fluxes in an Eastern Corn Belt Soil: Weather, Nitrogen Source, and Rotation," *Journal of Environmental Quality* 38:841-854.

Hey, D.L., L.S. Urban, and J.A. Kostel. 2005. "Nutrient Farming: The Business of Environmental Management," *Ecological Engineering* 24:279–287.

Hoag, D.L. and J.S. Hughes-Popp. 1997. "Theory and Practice of Pollution Credit Trading in Water Quality Management," *Review of Agricultural Economics* 19:252-262.

Horan, R.D., and J.S. Shortle. 2011. "Economic and Ecological Rules for Water Quality Trading," *Journal of the American Water Resources Association* 47(1):58-69.

Hutchinson, G.L., A.R. Mosier, and C.E. Andre. 1982. "Ammonia and Amine Emissions From a Large Cattle Feedlot," *Journal of Environmental Quality* 11:288-293.

Iowa Soybean Association. 2008a. "Managing Nitrogen for Economic and Environmental Performance," *On-Farm Network Update* (July):2-11.

Iowa Soybean Association. 2008b. "Understanding Soil Nitrogen Dynamics," *On-Farm Network Update* (October):2-11.

Jacobs, T.J., and J.W. Gilliam. 1985. "Riparian Losses of Nitrate From Agricultural Drainage Waters," *Journal of Environmental Quality* 14:472-478.

Jansson, M., R. Andersson, H. Berggren, and L. Leonardson. 1994. "Wetlands and Lakes as Nitrogen Traps," *Ambio* 23(6):320-325.

Jarecki, M.K., T.B. Parkin, A.S.K. Chan, T.C. Kaspar, T.B. Moorman, J.W. Singer, B.J. Kerr, J.L. Hatfield, and R. Jones. 2009. "Cover Crop Effects on Nitrous Oxide Emission From a Manure-Treated Mollisol," *Agriculture, Ecosystems, and Environment* 134:29-35.

Just, R. 1975. "Risk Aversion Under Profit Maximization," *American Journal of Agricultural Economics* 57(2): 347-352.

Khakural, B.R., and P.C. Robert. 1993. "Soil Nitrate Leaching Potential Indices: Using a Simulation Model as a Screening System," *Journal of Environmental Quality* 22(4):839-845.

Khosla, R., K. Fleming, J. Delgado, T. Shaver, and D. Westfall. 2002. "Use of Site Specific Management Zones To Improve Nitrogen Management for Precision Agriculture," *Journal of Soil and Water Conservation* 57:513-518.

King, D.M. 2005. "Crunch Time for Water Quality Trading," *Choices* 20(First Quarter):71-76.

King, D.M., and P.J. Kuch. 2003. "Will Nutrient Credit Trading Ever Work? An Assessment of Supply and Demand Problems and Institutional Obstacles," *Environmental Law Reporter* 33:10352-10368

Kirchmann, H., and L. Bergstrom. 2001. "Do Organic Farming Practices Reduce Nitrate Leaching?" *Communications in Soil Science and Plant Analysis* 32:997-1028.

Lander, C.H., D. Moffitt, and K. Alt. 1998. *Nutrients Available for Livestock Manure Relative to Crop Growth Requirements.* Resource Assessment and Strategic Planning Working Paper 98-1, U.S. Department of Agriculture, Natural Resources Conservation Service, February. (Available online at www.nrcs.usda.gov/technical/NRI/pubs/nlweb.html.) (Accessed September 10, 2009.)

Legg, J.O., and J.J. Meisinger. 1982. "Soil Nitrogen Budgets," in Stevenson, F.J. (ed.), *Nitrogen in Agricultural Soils*, Agronomic Monograph 22, American Society of Agronomy, pp. 503-557.

Lichtenberg, E. 2004. "Cost-Responsiveness of Conservation Practice Adoption: A Revealed Preference Approach," *Journal of Agricultural and Resource Economics* 29(3):420-435.

Lichtenberg, E., and B. V. Lessley. 1992. "Water Quality, Cost-Sharing and Technical Assistance: Perceptions of Maryland Farmers," *Journal of Soil and Water Conservation* 47(3): 260-264.

Liu, X., A. Mosier, A. Halvorson, and F. Zhang. 2006. "The Impact of Nitrogen Placement and Tillage on NO, N_2O, Ch_4 and CO_2 Fluxes From a Clay Loam Soil," *Plant Soil* 280(1):177-188.

Lowrance, R., L.S. Altier, J.D. Newbold, R.R. Schnabel, P.M. Groffman, J.M. Denver, D.L. Correll, J.W. Gilliam, J.L. Robinson, R.B. Brinsfield, K.W. Staver, W. Lucas, and A.H. Todd. 1997. "Water Quality Functions of Riparian Forest Buffer Systems in Chesapeake Bay Watersheds," *Environmental Management* 21:687-712.

Lowrance, R.R., R.L. Todd, and L.E. Asmussen. 1984. "Nutrient Cycling in an Agricultural Watershed: Streamflow and Artificial Drainage," *Journal of Environmental Quality* 13:27-32.

Malhi, S., and M. Nyborg. 1991. "Recovery of 15N-labelled Urea: Influence of Zero Tillage, and Time and Method of Application," *Fertilizer Research* 28(3):263-269.

Matson, P.A., W.J. Parton, A.G. Power, and M.J. Swift. 1997. Agricultural Intensification and Ecosystem Properties," *Science* 277:504-509.

Mayer, P.M., S.K. Reynolds, Jr., and T.J. Canfield. 2005. *Riparian Buffer Width, Vegetative Cover, and Nitrogen Removal Effectiveness: A Review of Current Science and Regulations.* EPA/600/R-05/118. U.S. Environmental Protection Agency, National Risk Management Research Laboratory.

McSwiney, C.P., and G.P. Robertson. 2005. "Nonlinear Response of N_2O Flux to Incremental Fertilizer Addition in a Continuous Maize (Zea mays L.) Cropping System," *Global Change Biology* 11:1712–1719.

Meisinger, J.J., and G.W. Randall. 1991. "Estimating N Budgets for Soil-Crop Systems," in R.F. Follett et al. (ed.), *Managing Nitrogen for Groundwater Quality and Farm Productivity*, American Society of Agronomy, p. 85-124.

Meisinger, J.J., and J.A. Delgado. 2002. "Principles for Managing Nitrogen Leaching," *Journal of Soil and Water Conservation* 57: 485-498.

Meisenger, J.J., J.S. Schepers, and W.R. Raun. 2008. "Crop Nitrogen Requirement and Fertilization," in J.S. Schepers and W.R. Raun (eds.), *Nitrogen in Agricultural Systems*, American Society of Agronomy, Crop Science Society of America, Soil Science Society of America.

Millar, N., G.P. Robertson, P.R. Grace, R.J. Gehl, and J.P. Hoben. 2010. "Nitrogen Fertilizer Management for Nitrous Oxide (N_2O) Mitigation in Intensive Corn (Maize) Production: An Emissions Reduction Protocol for US Midwest Agriculture," *Mitigation and Adaptation Strategies for Global Change* 15:185-204.

Mitsch, W.J., and J.W. Day. 2006. "Restoration of Wetlands in the Mississippi-Ohio-Missouri (MOM) River Basin: Experience and Needed Research," *Ecological Engineering* 26:55-69.

Mitsch, W.J., J.W. Day, Jr., J.W. Gilliam, P.M. Groffman, D.L. Hey, G.W. Randall, and N. Wang. 1999. *Reducing Nutrient Loads, Especially Nitrate-Nitrogen, to Surface Water, Ground Water, and the Gulf of Mexico: Topic 5 Report for the Integrated Assessment on Hypoxia in the Gulf of Mexico*. Decision Analysis Series No. 19, U.S. Department of Commerce, National Oceanic and Atmospheric Administration.

Mosier, A.R. and L. Klemedtsson. 1994. "Measuring Denitrification in the Field," in R.W. Weaver, S. Angle, P. Bottomley, D. Bezdicek, S. Smith, A. Tabatabai, and A. Wollum (eds.), *Methods of Soil Analysis: Part 2, Microbiological and Biochemical Properties*, Soil Science Society of America, pp. 1047-1065.

Mosier A.R., J.W. Doran, and J.R. Freney. 2002. "Managing Soil Denitrification," *Journal of Soil and Water Conservation* 57:505-513.

Musser, W.N., J.S. Shortle, K. Kreahling, B. Roach, W. Huang, D.B. Beegle, and R.H. Fox. 1995. "An Eonomic Analysis of the Pre-Sidedress Nitrogen Test for Pennsylvania Corn Production," *Review of Agricultural Economics* 17(1):25-35.

Nanda, V.P. 2006. "Agriculture and the Polluter Pays Principle," *American Journal of Comparative Law* 54:317-339.

Pennsylvania Department of Environmental Protection, 2008, *Final Trading of Nutrient and Sediment Reduction Credits – Policy and Guidelines, Appendix A*, Doc. No. 392-0900-001, Harrisburg, PA.

Peoples, M.B., J.R. Freney, and A.R. Mosier. 1995. "Minimizing Gaseous Losses of Nitrogen," in P.E. Bacon (ed.), *Nitrogen Fertilization in the Environment*, New York: Marcel Dekker, Inc., pp. 565-602.

Pionke, H.B., and R.R. Lowrance. 1991. "Fate of Nitrate in Subsurface Drainage Waters," in R.F. Follett, D.R. Keeney and R.M. Cruse (eds.), *Managing Nitrogen for Ground Water Quality and Farm Profitability*, Soil Science Society of America, pp. 237-57.

Power, J.F., R. Wiese, and D. Flowerday. 2001. "Managing Farming Systems for Nitrate Control: A Research Review From Management Systems Evaluation Areas," *Journal of Environmental Quality* 30 (November-December):1866-1880.

Rabalais, N.N., R.E. Turner, and W.J. Wiseman, Jr. 2002a. "Gulf of Mexico Hypoxia, A.K.A. "The Dead Zone," *Annual Review of Ecology, Evolution, and Systematics* 33:235-63.

Rabalais, N.N., R.E. Turner, and D. Scavia. 2002b. "Beyond Science Into Policy: Gulf of Mexico Hypoxia and the Mississippi River," *Bioscience* 52(2):129-142.

Rajsic, P., A. Weersink, and M. Gandorfer. 2009. "Risk and Nitrogen Application Levels," *Canadian Journal of Agricultural Economics* 57:223-239

Randall, G.W., J.A. Delgado, and J.S. Schepers. 2008. "Nitrogen Management To Protect Water Resources," in J.S. Schepers, W.R. Raun, R.F. Follett, R.H. Fox, and G.W. Randall (eds.), *Nitrogen in Agricultural Systems*. Agronomy Monograph 49, Soil Science Society of America, pp. 911-946.

Randall, G.W., M.J. Goss, and N.R. Fausey. 2010. "Nitrogen and Drainage Management To Reduce Nitrate Losses to Subsurface Drainage," in J.A. Delgado, and R.F. Follett (eds.), *Advances in Nitrogen Management for Water Quality*, Soil and Water Conservation Society.

Raun, W.R., and J.S. Schepers. 2008. "Nitrogen Management for Improved Use Efficiency," in J.S. Schepers, W.R. Raun, R.F. Follett, R.H. Fox, and G.W. Randall (eds.) *Nitrogen in Agricultural Systems*, Agronomy Monograph 49, Soil Science Society of America.

Ray, S.C. 1982. "A Translog Cost Function Analysis of U.S. Agriculture, 1939-77," *American Journal of Agricultural Economics* 64(3): 490-498.

Ribaudo, M.O. 2009. "Non-Point Pollution Regulation Approaches in the U.S," in J. Albiac and A. Dinar (eds.), *The Management of Water Quality and Irrigation Technologies*, London: Earthscan.

Ribaudo, M., and C. Nickerson. 2009. "Agriculture and Water Quality Trading: Exploring the Possibilities," *Journal of Soil and Water Conservation* 64(1):1-7.

Ribaudo, M.O. and J. Gottlieb. 2011. "Point-Nonpoint Trading – Can It Work?" *Journal of the American Water Resources Association* 47(1):5-14.

Ribaudo, M.O., and R.D. Horan. 1999. "The Role of Education in Nonpoint Source Pollution Control Policy," *Review of Agricultural Economics* 21(2):331-343.

Ribaudo, M., L. Hansen, D. Hellerstein, and C. Greene. 2008. *The Use of Markets To Increase Private Investment in Environmental Stewardship.* Economic Research Report No. 64, U.S. Department of Agriculture, Economic Research Service. (Available online at www.ers.usda.gov/publications/err64)

Ribaudo, M., N. Gollehon, M. Aillery, J. Kaplan, R. Johansson, J. Agapoff, L. Christensen, V. Breneman, and M. Peters. 2003. *Manure Management for Water Quality: Costs to Animal Feeding Operations of Applying Manure Nutrients to Land*, Agricultural Economic Report No. 824. U.S. Department of Agriculture, Economic Research Service. (Available online at www.ers.usda.gov/publications/aer824)

Ribaudo, M.O., R.D. Horan, and M.E. Smith. 1999. *Economics of Water Quality Protection From Nonpoint Sources: Theory and Practice.* Agricultural Economic Report No. 782, U.S. Department of Agriculture, Economic Research Service. (Available online at www.ers.usda.gov/publications/aer782)

Roberts, R.K., and E.O. Heady. 1982. "Fertilizer Demand Functions for Specific Nutrients Applied to Three Major U.S. Crops," *Western Journal of Agricultural Economics* 7(2): 265-278.

Robertson, D.M., G.E. Schwarz, D.A. Saad, and R.B. Alexander. 2009. "Incorporating Uncertainty Into the Ranking of SPARROW Model Nutrient Yields From Mississippi/Atchafalaya River Basin Watersheds," *Journal of the American Water Resources Association* 45(2):535-549.

Rochette, P., D.A. Angers, M.H. Chantigny, N. Bertrand, and D. Cote. 2004. "Carbon Dioxide and Nitrous Oxide Emissions Following Fall and Spring Applications of Pig Slurry to an Agricultural Soil," *Soil Science Society of America Journal* 68:1410-1420.

Roosen, J., and D.A. Hennessy. 2003. "Tests for the Role of Risk Aversion on Input Use," *American Journal of Agricultural Economics* 85(1):30-43.

Schepers, J.S., K. D. Frank, and C. Bourg. 1986. "Effect of Yield Goal and Residual Soil Nitrogen Considerations on Nitrogen Fertilizer Recommendations for Irrigated Maize in Nebraska," *Journal of Fertilizer Issues* 3:133-139.

Schlegel A.J., K.C. Dhuyvetter, and J.L. Havlin. 1996. "Economic and Environmental Impacts of Long-Term Nitrogen and Phosphorus Fertilization," *Journal of Production Agriculture* (9):114-118.

Shaffer, M.J., and J.A. Delgado. 2001. "Field Techniques for Modeling Nitrogen Management," in Follett et al. (ed.), *Nitrogen in the Environment: Sources, Problems, and Management.* Elsevier Science, pp. 391-411.

Shaffer, M.J., J.A. Delgado, C. Gross, R.F. Follett, and P. Gagliardi. 2010. "Simulation Processes for the Nitrogen Loss and Environmental Assessment Package (NLEAP)," in J.A. Delgado and R.F. Follett (eds.), *Advances in Nitrogen Management for Water Quality*, Soil and Water Conservation Society.

Sharpe, R.R., and L.A. Harper. 1995. "Soil, Plant, and Atmospheric Conditions as They Relate to Ammonia Volatilization," *Fertilizer Research* 42:149-153.

Sheriff, G. 2005. "Efficient Waste? Why Farmers Over-Apply Nutrients and the Implications for Policy Design," *Review of Agricultural Economics* 27(4):542-557.

Shortle, J.S. 1990. "Allocative Efficiency Implications of Water Pollution Abatement Cost Comparisons," *Water Resources Research* 26:793-797.

Shumway, R. 1983. "Supply, Demand, and Technology in a Multiproduct Industry: Texas Field Crops," *American Journal of Agricultural Economics* 65(4): 748-760.

Smith, R.A., G.E. Schwarz, and R.B. Alexander. 1997. "SPARROW Surface Water-Quality Modeling Nutrients in Watersheds of the Conterminous United States: Model Predictions for Total Nitrogen (TN) and Total Phosphorus (TP)." (Available online at http://water.usgs.gov/nawqa/sparrow/wrr97/results.html).

Turner, R.E., and N.N. Rabalais. 2003. "Linking Landscape and Water Quality in the Mississippi River Basin for 200 Years," Vol. 53 No. 6, *BioScience* 563-572.

Turner, R.E., N.N. Rabalais, D. Scavia, and G.F. McIsaac. 2007. "Corn Belt Landscapes and Hypoxia of the Gulf of Mexico," in J.I. Nassauer, M.V. Santelmann, and D. Scavia (eds.), *From the Corn Belt to the Gulf: Societal and Environmental Implication of Alternative Agricultural Futures*, Resources for the Future.

U.S. Department of Agriculture, Economic Research Service (USDA, ERS). 2010. "Direct Government Payments by Program, United States, 1996-2009," Farm Income: Data Files GP9609us. (Available online at www.ers.usda.gov/data/farmincome/finfidmuxls.htm#payments)

U.S. Department of Agriculture, Foreign Agricultural Service (USDA, FSA). 2011. "Corn at a Glance." (Available online at www.fas.usda.gov/htp/CP2011/Corn-2011-Final.pdf)

U.S. Department of Agriculture, National Agricultural Statistics Service (USDA, NASS). 2008. *Agricultural Statistics 2008*. (Available online at www.nass.usda.gov/Publications/Ag_Statistics/2008/index.asp.) (Accessed February 17, 2010.)

U.S. Department of Agriculture, Natural Resources Conservation Service (USDA, NRCS). 2010. *Assessment of the Effects of Conservation Practices on Cultivated Cropland in the Upper Mississippi River Basin*. (Available online at ftp://ftp-fc.sc.egov.usda.gov/NHQ/nri/ceap/UMRB_final_draft_061410.pdf)

U.S. Department of Agriculture, Natural Resources Conservation Service (USDA, NRCS). 2006. "Natural Resources Conservation Service Conservation Practice Standard: Nutrient Management," *National Handbook of Conservation Practice*.

U.S. Department of Agriculture – U.S. Environmental Protection Agency. (USDA-EPA) 1999. Unified National Strategy for Animal Feeding Operations. (Available online at http://cfpub.epa.gov/npdes/afo/ustrategy.cfm)

U.S. Environmental Protection Agency (EPA). 1992. *Another Look: National Survey of Pesticides in Drinking Water Wells, Phase II Report*, EPA 579/09-91-020.

U.S. Environmental Protection Agency (EPA). 2009. *National Summary of Impaired Waters and TMDL Information*. (Available online at http://iaspub.epa.gov/waters10/attains_nation_cy.control?p_report_type=T)

U.S. Environmental Protection Agency (EPA). 2010a. *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2008*, EPA 430-R-10-006.

U.S. Environmental Protection Agency, Office of Atmospheric Programs (EPA). 2010b. *Methane and Nitrous Oxide Emissions from Natural Sources*, EPA 430-R-10-001. April.

U.S. Environmental Protection Agency, Office of Wastewater Management (EPA). 2007. *Water Quality Trading Toolkit for Permit Writers*, EPA 883-R-07-004, August.

U.S. Environmental Protection Agency, Office of Water (EPA). 2004. *Water Quality Trading Assessment Handbook: Can Water Quality Trading Advance Your Watershed's Goals?* EPA 841-B-04-001.

Vanotti, M.B., and L.G. Bundy. 1994. "An Alternative Rationale for Corn Nitrogen Fertilizer Recommendations," *Journal of Production Agriculture* (7):243-249.

Vitosh, M.L., J.W. Johnson, and D.B. Mengel. 1995. *Tri-State Fertilizer Recommendations for Corn, Soybeans, Wheat and Alfalfa*. Extension Bulletin E-2567, Michigan State University, The Ohio State University, and Purdue University. (Available online at http://ohioline.osu.edu/ e2567/index.html.) (Verified June 3, 2010.)

Vitousek, P.M., J.D. Aber, R.W. Howarth, G.E. Likens, P.A. Matson, D.W. Schindler, W.H. Schlesinger, and D.G. Tilman. 1997. "Human Alteration of the Global Nitrogen Cycle: Sources and Consequences," *Ecological Applications* 73(3):737-750.

Weaver, R.D. 1983. "Multiple Input, Multiple Output Production Choices and Technology in the U.S. Wheat Region," *American Journal of Agricultural Economics* 65(1): 45-56.

Westermann, D.T., and G.E. Kleinkopf. 1985. "Nitrogen Requirements of Potatoes," *Agronomy Journal* 77:616-621.

Westermann, D.T., G.E. Kleinkopf, and L.K. Porter. 1988. "Nitrogen Fertilizer Efficiencies on Potatoes," *American Potato Journal* 65:377-386.

Williams, J.R., and D.E. Kissel. 1991. "Water Percolation: An Indicator of Nitrogen-Leaching Potential," in R.F. Follet, D.R. Keeney, and R.M. Cruse (eds.), *Managing Nitrogen for Groundwater Quality and Farm Profitability*, Soil Science Society of America, pp. 59-83.

Wisconsin Department of Natural Resources, 2002. *Agricultural Nonpoint Performance Standards and Prohibitions, NR 151, Subchapter 2.*

Woodward, R.T., and R. A. Kaiser. 2002. "Market Structures for U.S. Water Quality Trading," *Review of Agricultural Economics* 24:366-383.

Wu, J., and B.A. Babcock. 1998. "The Choice of Tillage, Rotation, and Soil Testing: Economics and Environmental Implications," *American Journal of Agricultural Economics* 80(3): 494-511.

Wulf, S., M. Maeting, and J. Clemens. 2002. "Application Technique and Slurry Co-Fermentation Effects on Ammonia, Nitrous Oxide, and Methane Emissions After Spreading: II Greenhouse Gas Emissions," *Journal of Environmental Quality* 31:1795-1801.

Xu, C., M.J. Shaffer, and M. Al-kaisi. 1998." Simulating the Impact of Management Practices on Nitrous Oxide Emissions," *Soil Science Society of America Journal* 62:736-742.

Appendix I

Estimating Water Treatment Costs

We estimated a treatment cost model with data from the 1996 American Water Works Association (AWWA) survey of its members. There are only 52 usable observations for which utilities provided all required data. This is the last survey in which data on costs and water quality (both raw water coming into and finished water going out of the utility) were gathered at the same time by AWWA. We assume this sample is representative of all water treatment plants. The model is a variable cost function with two outputs (one desirable (water) and one undesirable (nitrogen)); four inputs (three variable and one fixed); and nine factors hypothesized to influence production of drinking water (app. table 1.1).

The bootstrap method employed uses network density as the stratum—the result of this stratification is a more homogeneous sample and hence a smaller standard error.

Econometric specification of simple production model and discussion

$$\ln\left(\frac{V}{w_3}\right) = \hat{\beta}_o + \hat{\alpha}_1 \ln y + \hat{\alpha}_2 \ln N + \hat{\beta}_1 \ln\left(\frac{w_1}{w_3}\right) + \hat{\beta}_2 \ln\left(\frac{w_2}{w_3}\right) + \hat{\eta} \ln K$$

$\hat{\beta}_o$	$\hat{\alpha}_1$	$\hat{\alpha}_2$	$\hat{\beta}_1$	$\hat{\beta}_2$	$\hat{\eta}$
2.01***	0.80***	0.03***	0.62 ***	0.43***	0.03**
(4.55)	(81.50)	(2.69)	(16.82)	(5.22)	2.27)

$$\hat{\delta}_1 netd + \hat{\delta}_2 public + \hat{\delta}_3 dww + \hat{\delta}_4 syssize + \hat{\delta}_5 loc2 + \hat{\delta}_6 loc3 + \hat{\delta}_7 loc4 + \varepsilon$$

$\hat{\delta}_1$	$\hat{\delta}_2$	$\hat{\delta}_3$	$\hat{\delta}_4$	$\hat{\delta}_5$	$\hat{\delta}_6$	$\hat{\delta}_7$	
-0.00004***	0.14***	0.08***	0.05***	0.21***	0.22***	0.15***	(1)
(-94.50)	(4.65)	(4.96)	(4.19)	(5.53)	(4.77)	(2.93)	

Bootstrapped z in parenthesis. Significance level of 0.01 and 0.05 denoted by *** and **, respectively.

The estimated variable cost function meets most of the theoretical regularity conditions (i.e., it is monotonically increasing in desirable output as well as in variable inputs). The only case in which the desirable theoretical properties of inputs are not met is in the case of capital, which, in variable cost function setting, should be negative. The explanation resides in overcapitalization of water utilities—a phenomenon widely observed for regulated utility firms of all kinds. Homogeneity in the cost function is imposed by dividing both input prices and variable costs by price of chemicals. Consistent with the literature on undesirable outputs, the presence of an undesirable byproduct in a production process, in this case nitrogen, implies a higher cost to the utility which it then abates either to meet regulation[6] or more generally to reduce risk to customers.

[6]EPA regulates nitrate in drinking water (measured as nitrogen) at 10 mg/L.

Appendix Table 1.1
Summary statistics and definitions

Definition (unit) variable	Mean (Variance)	Definition (unit) variable	Mean (Variance)
Variable cost	8,479,039	System type	0.54
(in $) *VC*	(13,477,167)	(1 = Distribution and waste water, 0 = Otherwise) *dww*	(0.50)
Annual water production	14,449	System size	0.48
(in millions of gallons) *y*	(23,498)	(1 = if population served greater than 100,000, 0 = Otherwise) *syssize*	(0.50)
Annual salary	$34,353	Consumer structure	0.57
(in $) w_1	($11,538)	(ratio of residential to total water delivered) *cs*	(0.23)
Nitrogen abatement	0.98	Water system location	0.19
(in difference of raw-finished nitrates in water) (in mg/L) *N*	(4.04)	(New England) *loc1*	(0.40)
Electricity price	$0.05	Water system location	0.21
(in $ per kilowatt hour) w_2	($0.01)	(Northeast) *loc2*	(0.41)
Chemicals price	0.2	Water system location	0.15
in $ per pound) w_3	(0.0)	(South) *loc3*	(0.36)
Capital	$ 145,916,037	Water system location	0.21
(residual rate of return) *K*	(217,806,925)	(Mid-west) *loc4*	(0.41)
Network density	1176	Water system location	0.23
(population served/length of distribution main) *netd*	(5608)	(West) *loc5*	(0.43)
Organizational type	0.87		
(1 = public, 0 = otherwise) *public*	(0.34)		

Source: USDA, Economic Research Service using data from 1996 American Water Works Association survey.

As to the exogenous effects, network density has a negative effect on variable costs as expected. Also, larger systems have higher variable costs. Public utilities have higher variable costs than investor-owned utilities. This makes sense from the perspective that public firms may have agency and control problems relative to investor-owned enterprises. Operations that have only a distribution function have lower variable costs than those that have both waste water and distribution. All locations have higher variable costs relative to New England.

Derivation of shadow cost of nitrogen abatement and discussion

$$\hat{V} = \exp\begin{pmatrix} \hat{\beta}_o + \hat{\alpha}_1 \ln y + \hat{\alpha}_2 \ln N + \hat{\beta}_1 \ln\left(\frac{w_1}{w_3}\right) + \hat{\beta}_2 \ln\left(\frac{w_2}{w_3}\right) + \hat{\delta}_1 netd \\ + \hat{\delta}_2 public + \hat{\delta}_3 dww + \hat{\delta}_4 syssize + \hat{\delta}_5 loc2 + \hat{\delta}_6 loc3 + \hat{\delta}_7 loc4 \end{pmatrix} * w_3 \quad (2)$$

$$SC_N = \frac{\partial \hat{V}}{\partial N} = \hat{V} * \frac{\hat{\alpha}_2}{N} \qquad (3)$$

The shadow marginal cost of nitrogen abatement is derived in equation (3) by taking the derivative of (2), estimated variable cost, which in turn was derived by taking the exponential of (1). From equation (3), various additional derivations can be made: shadow marginal cost by millions gallons, $\partial \hat{V} / \partial N \; / \, y$, estimated shadow total variable cost of nitrogen abatement (SVC), $\partial \hat{V} / \partial N \times N$, and SVC per millions of gallons of water produced ($\partial \hat{V} / \partial N \times N$) $/ \, y$.

The results from the above derivations were used to estimate nitrogen removal costs by system size (app. table 1.2).

Appendix Table 1.2
National estimates of nitrogen removal costs for community water systems, by system size

System size (SS) [in millions of gallons per year] *(CWS population in parenthesis)*	Estimated average production by CWS *(millions of gallons per year)*	Estimated average cost of nitrogen removal *(variable cost per million gallons per year per CWS)*	Estimated total cost of nitrogen abatement *(million $ per year for all systems)*
SS > 0 and SS <= 3,300 (42,624)	570	$34.2 [46 %][1]	830
SS > 3,300 and SS <= 10,000 (4,871)	4,797	$25.55 [41 %][1]	597
SS > 10,000 (4,156)	42,485	$19.18 [31 %][1]	3,386

CWS = Community Water System.
[1]Percent of cost attributable.
Source: USDA, Economic Research Service using data from 1996 American Water Works Association survey.

Appendix 2

Using NLEAP To Model Nitrogen Losses

The Nitrogen Loss and Environmental Assessment Package (NLEAP) (Delgado et al., 2010a; Shaffer et al., 2010) can be used to assess the potential for management practices to increase nitrogen use efficiency and generate nitrogen savings that can be traded in water and air quality markets (Delgado et al., 2008b; 2010a). The NLEAP model has been used extensively across national and international systems (Delgado et al., 2008b).

This tool is capable of simulating the effects of management practices and generating reasonable assessment values that are similar to measured field studies conducted across small-scale plots and large commercial field operations (e.g., water budgets, nitrate leaching, residual soil nitrate, crop uptake, nitrogen dynamics, and N_2O emissions; Beckie et al., 1995; Khakural and Robert 1993; 2001; Delgado et al., 2001; Xu et al., 1998).

Detailed descriptions of NLEAP-GIS capabilities and limitations can be found in Shaffer and Delgado, 2001; Shaffer et al., 2010; Delgado and Shaffer, 2008; and Delgado et al., 2010a; 2010b. This improved version can quickly evaluate multiple long-term scenarios across a large number of soils and conduct assessments of the effects of BMPs on nitrogen use efficiency and nitrogen losses via different pathways. The new NLEAP-GIS tool also has a Nitrogen Trading Tool option (with GIS capabilities) (Delgado et al., 2008a; 2008b; 2010a; 2010b).

General assumptions

NLEAP has been tested, calibrated, and used to accurately evaluate the effects of management for cropping systems and risky landscape combinations across national and international agroecosystems. In order to evaluate these systems, users established basic assumptions to simplify the evaluation process, which is very complex due to the nature of the nitrogen cycle and management interactions with environmental factors (Shaffer and Delgado, 2001).

Yields: It is well known that yield variability can impact nitrogen use efficiency (Bock and Hergert, 1991). Instead of using the maximum yields at a given site as traditionally done by farmers as a safety net approach to calculating nitrogen inputs (Bock and Herget, 1991), State average yields for corn and soybeans derived from the USDA Census of Agriculture were used for the NLEAP-GIS simulations.

We assumed that yields for no-till systems were 10 percent lower than those for conventional tillage. Since we also evaluated excessive nitrogen input scenarios and low nitrogen input (deficit) scenarios, we used the corn yield and nitrogen input response curve from Bock and Herget (1991) to estimate the average yields for these scenarios. It was assumed that for the excessive nitrogen input rates, yields were increased by only 1 percent; however, for the deficit nitrogen input scenario a 10-percent drop in average yield was assumed (Bock and Herget, 1991). We believe that our approach of using average yields to evaluate the effects of management on the nitrogen use efficiency of commercial systems is a valid approach, as reported by Shaffer and Delgado (2001), Delgado (2001), and Delgado et al. (2000; 2001).

Since the USDA Census of Agriculture does not report yields by soil type, we assumed that yields for the soil types tested were similar. However, corn yield can vary among soil type, with lower yields in the sandier, less fertile soils that have higher nitrate leaching potential than those finer soils with lower leaching potential (Khosla et al., 2002; Bausch and Delgado, 2003; Delgado and Bausch, 2005; Delgado et al., 2005). Nonetheless, we still believe that assuming average yields for a 24-year period being evaluated is a valid approach to assessing the trends and effects of management practices on these different soil types and produces results that are in agreement with average measured values (Delgado et al., 2001; 2008b; 2010a). If additional site-specific field information for a given farm is needed, spatial soil maps for the given farm can be downloaded from USDA NRCS websites, and evaluations using farmers' inputs can be conducted.

Nitrogen Inputs and Uptake: For nitrogen rates, we used the recommended best management practices for site-specific State and/or soil as described by Espinoza and Ross (2008) for Arkansas; Alley et al. (2009) for Virginia; Beegle and Durst (2003) for Pennsylvania; and Vitosh et al. (1995) for Ohio. We calculated the recommended nitrogen (N) rate per bushel of corn derived from each State's recommended BMPs (Espinoza and Ross, 2008; Alley et al., 2009; Beegle and Durst, 2003; Vitosh et al., 1995). A summary of the nitrogen inputs simulated is presented in appendix table 2.1.

Since nitrogen fertilizer inputs were calculated based on yield, the no-till systems received lower nitrogen fertilizer inputs than the conventional systems. However, since a similar rate of uptake per unit of bushel was used for both systems, the removal of nitrogen in harvested grain from the no-till system was also lower than the removal of nitrogen in the grain from the higher yield conventional system. Total nitrogen uptake by the plant was calculated. Initial surface residue cover was simulated at 100, 90, 40, and 30 percent for no-till corn-corn, no-till corn-soybeans, conventional corn-corn, and conventional corn-soybeans, respectively.

For the manure system, manure was applied every 2 years. For the corn-corn rotation, manure was applied in the first year, and only fertilizer was applied in the second year. The manure rate was calculated for each system to match the fertilizer rate. However, since manures will have a large fraction of organic nitrogen that is not immediately available (Davis et al., 2002; Eghball et al., 2002), an additional 50 percent of the recommended rate was added as inorganic nitrogen fertilizer. In other words, the total nitrogen input during the first year of corn-corn rotation was 150 percent of the total application rate of the inorganic nitrogen fertilizer scenario (app. table 2.1). The corn-corn rotation did not receive any manure application in the second year, and the corn received the same rate of nitrogen fertilizer as in the nitrogen-fertilizer-only scenario. Thus, over the 2-year period, the manure scenario for corn-corn received an average of 25 percent more nitrogen input per year. The same relationships apply to the excessive and deficit nitrogen scenarios (app. table 2.1).

Appendix Table 2.1
Relationships used to develop yields and nitrogen (N) rates used across the study sites

Tillage	Best management practice	Excessive	Deficiency
		Yield (bushels per acre)	
Conventional	x[1]	x*1.01	x*0.9
No-till	x*0.9	x*0.9*1.01	x*0.81
		N rate for fertilizer-only scenarios (lbs N per acre)	
Conventional	x[2]	z*1.75	z*0.75
No-till	y[3]	y*1.75	y*0.75
		N rate for manure with N fertilizer scenarios (lbs N per acre)	
Conventional	z(org) + 0.5z(fert)	1.75z(org) + z(0.875)	0.75z(org) + z(0.375)
No-till	y(org) + 0.5y(fert)	1.75y(org) + y(0.875)	0.75z(org) + z(0.375)

[1]The x values were 131, 101, 103, and 107 corn bushels per acre for OH, VA, PA, and AR, respectively. The x values were 40, 27, 37 and 27 soybean bushels per acre for OH, VA, PA, and AR, respectively.

[2]The z values were 132, 121, 100, 120, and 125 lbs of N per acre for OH, VA, PA, AR (Hydrology A) and AR (Hydrology D), respectively, for conventional tillage.

[3]The y values were 116, 109, 90, 100, and 105 lbs of N per acre for OH, VA, PA, AR (Hydrology A) and AR (Hydrology D), respectively, for conventional tillage.

Source: USDA, Economic Research Service using data from USDA, Agricultural Research Service.

For the corn-soybean rotation, there was no application of nitrogen fertilizer or manure for any of the scenarios during the soybean year (app. table 2.1). Additionally, for this rotation, the nitrogen cycling from the leguminous soybean crop was credited, as is recommended for each State, so the calculated nitrogen inputs for the corn in the corn-soybean rotation was lower than in the corn-corn system.

The excessive nitrogen fertilizer scenarios received 75 percent higher nitrogen inputs than the State-recommended rate. For the deficit nitrogen application scenarios, nitrogen inputs were applied at a 25-percent lower nitrogen rate than the best management practice scenario (app. table 2.1).

Soil Type Physical and Chemical Information: For each State, the county's soil chemical and physical information averages for the selected soils were downloaded. To evaluate all of the management scenarios described above, we selected a soil with a higher leaching potential (Hydrology A or B) and a soil with a lower leaching potential (Hydrology C or D).

Long-Term Weather: Long-term USDA, Natural Resources Conservation Service weather databases for each county were used to conduct the 24-year assessment as described by Delgado et al. (2008b, 2010a) nitrogen trading tool evaluations.

Other Best Management Practices Tested: For all the scenarios described above, we evaluated the method of application. The best management practice for method of application was incorporation of nitrogen fertilizer and/or manure. Surface application without incorporation was found to be a poor management practice. We also evaluated time of application. The best management practice for time of application was application of manure and/or nitrogen fertilizer before planting, closer to the time of higher demand by the crop. The poor management scenario was application of manure and/or fertilizer the previous fall, when the nitrogen is more susceptible to losses.

Long-Term Evaluations: All these scenarios were evaluated over the long term. To conduct the long-term evaluations, we used a 24-year period using long-term weather data for the given county. Similar to what was done with the nitrogen trading tool, the first 12 years were used to run the model, and years 13 to 24 were used to evaluate the effect of management practices on nitrogen use efficiency and on reactive losses to the environment (Delgado et al., 2008b, 2010a).

Appendix 3

Estimating Changes in Nitrogen Fertilizer Application Rate

This appendix describes the econometric model used to estimate changes in nitrogen (N) fertilizer application rate. We estimate nitrogen application rates using an instrumental variables (IV) approach to overcome identification issues presented by farmer heterogeneity and endogenous soil N-testing. Price plays an important role in the nitrogen management decision, and the recent price growth of nitrogen has implications for nitrogen management behavior and by extension, nitrogen use efficiency (NUE). Notably, we instrument for nitrogen price using a cross-section of data by exploiting exogenous spatial variation between domestic ammonia production plants and cornfield locations.

Research using observational data presents econometric challenges, and this is particularly true for research examining the effect of potentially endogenous variables on a study population. For example, when estimating the effect of N-soil tests on application rate, researchers do not know why two observationally identical farmers make different choices about testing the soil. The underlying problem is the concern that unobserved farmer characteristics are responsible for determining whether the farmer conducts a test. For example, a farmer who tests the soil regularly may also have unobserved preferences for land stewardship. If differences beyond observed field, farm operation, and operator characteristics play a role in determining who conducts the test and how the test is used, then the test may be endogenous to the amount applied.

Nitrogen price also presents a challenge in a sample of microdata. Prices are likely to embody an error-in-variables problem because in the case of ARMS, they were created as a share variable that represents the nitrogen fertilizer's relative size of the total expenditures for all fertilizer (nitrogen, phosphorus, and potassium). To see how this effects the estimation of nitrogen demand, consider that we observe nitrogen price as a function of the true, unobserved price plus a disturbance term, v.

$$(1) \qquad \text{Price}_N\text{Observed} = \text{Price}_N\text{True}^* + v\,.$$

Because the observed price on the left-hand side of equation (1) is a function of true price and v, an ordinary least squares (OLS) model of nitrogen demand estimated with the observed price will include v and will cause the estimate to be biased and inconsistent. Specifically, in the classic errors-in-variables example, the coefficient in an OLS model will be biased toward zero.[7] Prices farmers pay may also change with their level of demand. For example, if farmers receive quantity discounts when purchasing nitrogen fertilizer and their application rate is correlated with total nitrogen demand, then failing to account for this also results in bias.

[7] See Greene (2000) for a formal discussion of measurement error and the resulting attenuation bias.

To overcome the problem of mismeasured nitrogen prices and endogenous soil testing, we employ an IV approach, which allows for the development of consistent and unbiased estimates. In the case of endogenous N-soil testing, we find a set of instruments that are correlated with N-soil testing but uncorrelated with disturbance process: average annual soil percolation and average annual precipitation. Because percolation facilitates nutrient leaching (Williams and Kissell, 1991), we expect the greater soil percolation to increase uncertainty about available nutrients, and, therefore, encourage soil testing. Higher precipitation generally reduces the ability to conduct soil test, therefore we expect annual average precipitation to be negatively related to N-soil test.

We identify the nitrogen own-price effect on demand using three sources of exogenous variation: distance between the field and domestic ammonia fertilizer production; production capacity of nearby ammonia plants; and distance from the field to New Orleans, LA, site of the majority of international ammonia importation.[8] Ammonia is increasingly being imported by the United States, and a majority of shipments enter from the Gulf of Mexico, and specifically, New Orleans; therefore, we also include a distance-to-New Orleans measure. These variables are useful instruments because the distance between the field and production capacity are arguably uncorrelated with the behavior of the farmer or the placement of the field;[9] therefore, the instruments allow one to capture the exogenous variation in price and use it to estimate application rates.

Instrumental variables model

We use an IV model specified with two endogenous variables to estimate a partial-equilibrium static demand model derived from profit maximization theory. The model assumes producers make immediate adjustments to quantity demanded in response to changes in price, and that prices are known at the time of production planning. These assumptions are reasonable given the ability of farmers to enter into contracts that establish price for delivered corn and inputs to production, such as forward or marketing contracts, and other hedging instruments. Further, production technology is assumed known and fixed. Since only two time periods separated by 4 years are used, technology is unlikely to change. The most likely technological change is that of seed technology—the use of biotech (Bt) corn; however, the model specification controls for this. In 2001, 20 percent of corn acres were planted with Bt corn; in 2005, the amount was slightly greater than 30 percent.

We characterize the problem posed to the farmer as one of profit maximization with uncertainty, as evidenced by the nitrogen overtreatment, but the decision of the farmer could also be conceptualized as a utility maximization problem. In this case, the farmer chooses a level of output that maximizes the farmer's initial wealth plus expected profit from the operation. Under utility maximization, a farmer considers not only expected profit but moments of the profit distribution as well, and deviations from the recommended level of nitrogen then depend on the farmer's level of risk aversion. Evidence from field trial suggests that risk-neutral farmers would be willing to overapply nitrogen to increase profits during a year of "good" growing conditions (Rajsic et al., 2009). On the other hand, risk-averse farmers will reduce their nitrogen rate to reduce profit variance. In practice, our empirical results are not dependent on the conceptual framework; in both cases, nitrogen prices enter the profit function, and the identification strategy would not change. Rather, the level of risk aversion primarily drives the differences. Some

[8]Ammonia production data come from the *North American Fertilizer Capacity Annual Reports* issued by the International Fertilizer Development Center. We calculate the distances from the field to ammonia production using the location of the plant and geocoded corn field samples from USDA's 2001 and 2005 Agricultural Resource Management Survey. It should be noted that these are sample points, and they do not represent all corn production in the United States; however, when we estimate a model of nitrogen demand, the sample points are weighted to reflect total U.S. corn production.

[9]To test that the instruments are uncorrelated with the residual component in the second stage of the IV model, or exogenous to the rate of fertilizer application, we test overidentification restrictions using a Sargan test. The test statistic is computed as $n \times R^2$ and has a $\chi^2(k\text{-}r)$ distribution, where k is the number of instruments and r is the number of endogenous variables. The results of the test are presented in the results table.

research, however, suggests that risk-averse farmers are more responsive to price because of profit risk (Just, 1975; Roosen and Hennessy 2003; Rajsic et al., 2009), and, if farmers are on average risk averse, our elasticity estimates will represent an upper bound.

Equation (2) is the outcome equation where Y represents the log transformed per acre rate of nitrogen applied to the field of farm i in USDA production region r at time t. Endogenous variables, $\hat{T}$ and $\hat{P}$, are estimated N-soil testing probability and nitrogen price from equations (3) and (4). The set of excluded instruments for N-soil test are represented by Z^T, and the excluded instruments used to estimate nitrogen price are represented by Z^P. The vector X is a set of independent variables that includes characteristics of the operator, farm operation, and the field; the disturbance term is represented by ε.

$$Y_{irt} = \alpha_1 + \hat{T}_{irt}\beta_1 + \hat{P}_{irt}\lambda_1 + \mathbf{X}_{irt}\delta_1 + \phi_{1r} + \upsilon_{1t} + \varepsilon_{irt}\,,$$

$$T_{irt} = \alpha_2 + \mathbf{X}_{irt}\beta_2 + Z^T{}_{irt}\delta_2 + \phi_{2r} + \upsilon_{2t} + \kappa_{irt}\,,$$

$$P_{irt} = \alpha_3 + \mathbf{X}_{irt}\beta_3 + Z^P{}_{irt}\delta_3 + \phi_{3r} + \upsilon_{3t} + u_{irt}\,.$$

A case can be made that countrywide trends over time affect the use of nitrogen. Perhaps in response to outreach efforts to reduce fertilizer runoff due to overuse, for example, environmental awareness campaigns that communicate the benefits of reduced nitrogen in the environment, attitudes about nitrogen rates have changed. We control for trends in nitrogen use that change over time with a time effect term, υ_t. As well, use of nitrogen across production USDA-defined regions may also affect application rates, therefore we control for region-specific factors with a fixed-effect term, ϕ_r.

Data

The data are cross-sectional and come from USDA's Agricultural Resource Management Survey (ARMS). ARMS comprises responses to a series of interviews with farm operators designed to solicit information about production practices, costs of production, business finances, and operator and household characteristics. Commodity specific surveys are fielded on a rotating basis, usually every 5 to 8 years. We focus on corn production because of its intense use of nitrogen, for which ARMS last fielded surveys in 2001 and 2005.

We use data from two components of ARMS. The first component is the *Corn Production Practices and Costs Report*, which surveys the farm enterprise's costs of production and a host of production practices at the field level. The second component is the *Corn Costs and Returns Report*, which collects indepth financial information concerning the farm business and the household of the operator. The two components can be linked together to provide a complete view of the farm operation from the farm's representative field to its financial statement, and we restrict the sample to farmers who completed both surveys.

As covariates, we include the farmer's age, education, and income earned from work off the farm. We account for land quality and tenancy issues by including the per acre annual value of production, the per acre value of the land, and acres owned by the operator. We also control for environmental characteristics of the field, for example, whether any part of the field is a classified as a wetland. The presence of livestock and a nutrient management plan on the farm may indicate a greater reliance on manure, driven often by the need to dispose of manure. We account for these with dummy variables as well. The nutrient requirements of a current corn crop are also based, in part, on the plant-available nutrients existing in the soil, and past cropping practice can influence these nutrients. Therefore, we use a dummy variable to control for crop rotation pattern of 3-year straight corn rotation.

The timing and method of application may also be important determinants of application rate. A spring application is better timed to meet the plant's need for nutrients and reduces the risk of loss due to environmental factors relative to a fall or winter application. On the other hand, farmers may opt to apply nitrogen in the fall, when there are fewer time demands and prices are often lower. In such a case, a nitrogen inhibitor is often used to further slow the nitrification process, though average annual nitrate losses can still be 50 percent higher under fall application than under spring application (Randall and Mulla, 2001). To counter this, in many cases, anhydrous ammonia is injected into the soil because low temperatures at this time of year slow the conversion of ammonia to ammonium and nitrate, reducing the loss of nitrogen. We control for the method of application with a dummy variable indicating whether the nutrient was incorporated or injected into the soil.

Technology and other management practices thought to affect nitrogen rate are captured by explanatory variables indicating the use of field irrigation and biotech (Bt) corn seed. Irrigation is an important component in nitrogen management. Irrigation may be a necessary practice due to the climate, or it may be another way of more precisely controlling growing conditions. If water and nitrogen are complementary inputs, the presence of irrigation should increase the rate of nitrogen application. The use of biotech seed is driven by the associated cost reductions from the technology's herbicide, pest, or fungus resistance. We also include a dummy variable representing whether the corn crop was grown for silage or corn. A full list of covariates and summary statistics is presented in appendix table 3.1.

Outcome Measures

We estimate the application rate for four different permutations of nitrogen fertilizer use. First, we estimate commercial nitrogen use by farmers who exclusively apply commercial nitrogen—a group that accounts for a 78 percent of the farmers in our sample. We also examine the rate of total commercial nitrogen use by all farmers, regardless of whether they used commercial nitrogen exclusively or in conjunction with manure. The third measure examines the sensitivity of commercial nitrogen use by farmers who use manure in conjunction with commercial nitrogen—a group that employs an imperfect substitute for commercial nitrogen. These farmers make up a minority of the sample, 22 percent. Finally, we examine the effect of our explanatory variables on total nitrogen application rate, which includes commercial nitrogen and manure. It should be noted that all of the farmers in the sample reported at least some use of commercial nitrogen fertilizer. Estimates from the IV model are presented in appendix table 3.2.

Appendix Table 3.1
Summary statistics

Variable name	Description	Mean	95% confidence	Interval
Soiltestn	Nitrogen soil test	0.21	0.18	0.24
Nprice	Nitrogen price	0.328	0.324	.332
Dealerrec	Dealer recommendation	0.32	0.29	0.35
Consultrec	Consultant recommendation	0.14	0.12	0.16
Extrec	Extension agent recommendation	0.04	0.02	0.05
Routine	Routine practice	0.28	0.26	0.30
op_age	Operator's age	52.73	52.11	53.36
Retired	Operator is retired from farming	0.04	0.03	0.06
College	Operator holds college degree	0.35	0.31	0.37
Workoff	Derive income from off-farm work	0.38	0.35	0.42
Anycropins	Insurance participation rate	0.659	0.62	0.70
Prodvalpa	Production value per acre	$4,	372.57	$337.29
Landvalpa	Land value per acre	$1,616.55	$709.46	$2,523.64
Ownacre	Acres owned	323.37	301.10	345.63
Corn_p	Corn price	1.87	1.84	1.90
CCC	Straight corn rotation (3 years)	0.25	0.21	0.28
Nutrient plan	Nutrient plan in place	0.076	0.063	0.088
Irrigate	Irrigate the field	0.063	0.0397	0.0853
Wetland	Wetland on any part of the field	0.03	0.02	0.04
Tenure	Years farming	27.61	26.89	28.33
Spring	Spring fertilizer application	0.80	0.77	0.84
Inc	Incorporated fertilizer	0.75	0.73	0.78
Inhibit	Fertilizer applied with inhibitor	0.07	0.05	0.09
Bt_corn	Biotech corn	0.34	0.30	0.38
Yldgoal	Yield goal	173.62	166.31	180.94
Silage	Corn for silage	0.11	0.09	0.13
Livestock	Presence of livestock on the farm	0.576	0.55	0.602
Commercial nitrogen w/o manure	Commercial nitrogen users only	129.72	125.67	133.77
Total commercial nitrogen	Total commercial nitrogen use	118.42	114.42	122.42
Commercial nitrogen w/ manure	Commercial nitrogen use by manure users	77.23	70.60	83.87
	Total commercial nitrogen and manure use	137.59	132.16	143.02
Total nitrogen observations		2,874		

Source: USDA, Economic Research Service using data from USDA's 2001 and 2005 Agricultural Resource Management Survey.

Appendix Table 3.2

IV estimates of nitrogen application rate

	Commercial nitrogen: nonmanure users	S.E.	Total commercial nitrogen	S.E.	Commercial nitrogen: only manure users	S.E.	Total nitrogen (manure and nonmanure users)	S.E.
Soiltestn	-0.924**	0.290	-1.142**	0.336	0.333	0.742	-1.080**	0.308
Lognprice	-1.347	0.715	-1.379*	0.630	0.531	1.408	-0.674	0.589
Dealerrec	0.131**	0.043	0.159**	0.047	0.155	0.099	0.157**	0.042
Consultrec	0.229**	0.078	0.291**	0.083	-0.004	0.171	0.303**	0.078
Extrec	0.084	0.086	0.143	0.084	0.239	0.156	0.163*	0.073
Routine	-0.170**	0.065	-0.164**	0.063	-0.071	0.100	-0.136**	0.057
Op_age	-0.011**	0.003	-0.008**	0.003	0.005	0.007	-0.008**	0.002
Retired	0.104	0.098	0.107	0.100	0.171	0.211	0.002	0.089
College	0.043	0.034	0.055	0.037	0.118	0.117	0.025	0.034
Workoff	-0.091**	0.037	-0.0810*	0.0398	-0.124	0.094	-0.115**	0.037
Anycropins	0.061	0.054	0.1065*	0.0498	0.035	0.083	0.1203**	0.0468
Prodvalpa	-7.84E-06	3.32E-05	-3.09E-05	2.50E-05	-4.38E-05	3.25E-05	4.64E-05**	1.98E-05
Landvalpa	-4.93E-07	4.41E-07	-8.96E-07	7.65E-07	-5.21E-05	2.81E-05	-1.57E-06	8.10E-07
Ownacre	3.62E-05**	1.37E-05	3.92E-05**	1.48E-05	-6.32E-05	5.88E-05	2.95E-05	1.51E-05
logcorn_p	0.006	0.043	0.029	0.048	-0.032	0.112	0.034	0.045
Ccc	0.0315	0.055	0.092	0.052	0.192**	0.088	0.082	0.051
Wetland	-0.081	0.118	-0.065	0.110	-0.187	0.326	-0.013	0.098
Nutrplan	0.167**	0.070	0.023	0.077	-0.280**	0.133	0.172**	0.072
Irrigate	0.527**	0.085	0.532**	0.089	-0.370	0.364	0.551**	0.084
Tenure	0.006**	0.002	0.005**	0.002	0.005	0.007	0.004	0.002
Spring	0.028**	0.041	0.013	0.048	-0.083	0.150	0.026	0.042
Inc	0.063	0.050	0.061	0.049	0.052	0.101	0.053	0.046
Inhibit	0.083	0.057	0.2239**	0.0590	0.556**	0.120	0.176**	0.056
Bt_corn	0.042	0.036	0.067	0.040	0.081	0.100	0.062	0.036
Yldgoal	0.001**	0.0002	0.0003	0.0002	-5.27E-06	2.23E-04	0.0001	0.0002
Silage	-0.404**	0.093	-0.350**	0.078	-0.060	0.094	-0.098	0.076
Live	-0.154**	0.046	-0.233**	0.051	-0.265	0.186	-0.142**	0.047
Observations	2253		2874		624		2874	
F-Statistic	6.69 [<0.000]		11.87 [<0.000]		6.31 [<0.000]		7.82 [<0.000]	

Source: USDA, Economic Research Service using data from USDA's 2001 and 2005 Agricultural Resource Management Survey.

Appendix 4

Comparing Costs of Farms Using Different Nutrient Management Practices

The goal of this analysis was to estimate the variable production costs for farms using different nutrient management strategies. The results are used to estimate the cost of changing from a less-efficient to a more-efficient nutrient management strategy. We restricted our analysis to corn, given the large acreage and its intensive use of nitrogen.

Data on corn are from USDA's 2001 Agricultural Resource Management Survey (ARMS). This is the last corn survey from which field-level cost of production data are estimated for each observation. SAS General Linear Model procedure (GLM) was used to estimate a model of variable production costs as a function of management and resource-base variables. Least squares means were used to compare the per acre variable production costs between practices directly related to nitrogen management.

Total variable costs (TVC) were defined as the costs of seed, fertilizer, manure, pesticides, custom work, and fuel lubricants. We specified a model of TVC as a function of the following variables:

(1) Use of biotech or herbicide resistant corn
(2) Use of rotation with soybeans
(3) Use of nitrogen inhibitor
(4) Tillage (conventional till vs. reduced/no till)
(5) Timing (fall vs. spring application)
(6) Method (broadcast vs. inject/incorporate)
(7) Conservation cropping (contour or strip)
(8) Presence of nutrient management plan
(9) Use of variable rate technology
(10) Presence of irrigation
(11) Presence of highly erodible soils (yes or no)
(12) Presence of tile drains
(13) Growing season (northern tier, middle tier, southern tier)
(14) Farm size (total corn acres on farm)
(15) Yield goal

An interaction term for timing and method (fall/no fall – incorporate/broadcast) was also included. The cost model was run separately for those farms that do not use manure and for those farms that use both manure and commercial fertilizer. About 16 percent of U.S. corn acres receive manure.

Since most of the variables are class variables, we used the SAS General Linear Model procedure (GLM) to estimate the model. The R-Squares of the no-manure and manure-cost models are 0.21 and 0.16, respectively, and the models are significant at the 1-percent level. The majority of the explanatory variables are statistically significant at the 5-percent level. Least-square means of the production costs ($/acre) under the different management systems are presented in app. table 4.1, along with an indication of whether the difference is statistically significant. Of interest to this study is that the cost under the preferred method/timing combination (spring/incorporate) is significantly different from the costs under the less-preferred, alternative combinations (at the 5- and 10-percent levels) for those farms that use only commercial fertilizer (84 percent of treated corn acres). No significant differences in costs were found for farms that use both manure and commercial fertilizer.

Part of the difference in costs observed with ARMS data is due to differences in chemical application rates. Since the NLEAP scenarios assumed the management changes were independent, altering rate, timing, and method in different combinations, we needed to separate out the nitrogen fertilizer cost from the total of changing management. We ran the same models, but with nitrogen application rate as the dependent variable. Both of the models were

Appendix Table 4.1
Variable cost per acre of management practices

	Commercial nitrogen only		Commercial nitrogen and manure	
	Dollars per acre	*Pr > t*	*Dollars per acre*	*Pr > t*
Management choice				
Continuous corn	131.23	.0001	165.63	.1330
Rotation with soybeans	124.02		158.06	
Conventional tillage	128.79	.1554	128.79	.6671
Reduce/no-till	126.46		126.46	
Fall/broadcast	127.84	.0582	158.89	.1587
Fall/incorporate	128.39	.0557	155.25	.1867
Spring/broadcast	132.54	.0001	158.53	.2078
Spring/incorporate	121.74		174.70	
No irrigate	133.33	.0009	164.11	.7292
Irrigate	121.92		159.58	
No highly erodible soil	124.92	.0088	157.98	.2013
Highly erodible soil	130.34		165.71	
No nitrogen inhibitor	125.34	.0832	153.80	.0441
Nitrogen inhibitor	129.92		169.88	
No conservation cropping	131.83	.0004	163.25	.6278
Conservation cropping	123.42		160.44	
No nutrient plan	127.87	.8475	157.63	.1461
Nutrient plan	127.39		166.06	
No variable rate technology	125.45	.1522	155.39	.2945
Variable rate technology	129.81		168.30	
No tiles	128.79	.2095	168.02	.0366
Tiles	126.46		155.67	

Source: USDA, ERS using USDA's 2001 Agricultural Resource Management Survey.

significant, with R-squares of 0.23 and 0.24. Differences in application rates between the spring/inject and the other management combinations were positive (as expected) and significant at the 1-percent level for farms using only commercial fertilizer (app. table 4.2). The difference in nitrogen fertilizer costs was subtracted from the cost difference derived from the cost model, using a nitrogen fertilizer price of $0.30/lb. The cost of adopting appropriate method (assuming no change in fertilizer application rate) was estimated to be $7.35/acre, appropriate timing was $3.01 per acre, and both appropriate method and timing were $1.86/acre. For farms using manure, we assumed no differences in costs.

Appendix Table 4.2

Nitrogen application rates per acre by management practice

	Commercial nitrogen only		Commercial nitrogen and manure	
	Pounds per acre	*Pr > t*	*Pounds per acre*	*Pr > t*
Management choice				
Continuous corn	136	.1544	218	.0420
Rotation with soybeans	140		192	
Conventional tillage	137	.3583	202	.6433
Reduce/no-till	139		208	
Fall/broadcast	143	.0001	191	.0420
Fall/incorporate	141	.0042	201	.6433
Spring/broadcast	140	.0001	220	.8382
Spring/incorporate	129		208	
No irrigate	129	.0002	210	.7692
Irrigate	147		200	
No highly erodible soil	139	.5955	222	.0353
Highly erodible soil	137		188	
No nitrogen inhibitor	135	.0017	189	.1354
Nitrogen inhibitor	141		221	
No conservation cropping	143	.0004	175	.0001
Conservation cropping	133		235	
No nutrient plan	137	.6002	197	.2950
Nutrient plan	139		213	
No variable rate technology	138	.9899	224	.3175
Variable rate technology	138		186	
No tiles	139	.4957	214	.2384
Tiles	137		196	

Note: Parameter estimates from GLM model.

Source: USDA, Economic Research Service using data from USDA's 2001 Agricultural Resource Management Survey.

Appendix 5

Estimating Wetland Restoration Costs

The cost of restoring a wetland is the sum of the cost of the land and the cost of restoring the land's water-hold capability and the wetland ecosystem. We generate wetland and restoration costs using cost functions that we estimated using available wetland cost data. Sample observations lie in the Glaciated Interior Plains (GIP).

The cost of the land to society is the difference in its value with and without the wetland. The value of agricultural land without a wetland is assumed to be a function of the net value of its output, but the potential for nonagricultural use can play a role.

The USDA Wetland Reserve Program (WRP) sets wetland easement prices equal to the difference in land values with and without a permanent wetland easement. Therefore, WRP easement payments are well suited as a measure of land cost.

Land cost is modeled as a function of the agricultural value and value squared of the land in the contract (AgrValue and AgrValuesq), contract size and size squared (Acres and Acressq), the potential for urban development (Urban), and farm size (Fsize). Because a measure of the agricultural value of the land is not available, we use the product of the county-average farmland rental rate (Rent) and contract acreage as a proxy (it represents the annual agricultural value of the land).

The adjusted R-square of the estimated land cost model indicates that the estimated ordinary least squares model explains 90 percent of the variation in WRP land costs. Variables are statistically significant and have the expected sign. With this cost function, we generate marginal and average land cost estimates by county throughout the GIP. To generate average cost, we divide total land cost (generated with our model) by the size of the contract—all cost estimates are based on the median-size WRP easement. Across the counties of the GIP, average per acre costs range from \$1,490 to \$3,030.

Second, we generate the marginal cost function (MC_L) by differentiating the estimated land-cost model with respect to Acres:

$$MC_L = 925 + 4.32*Rent + 2.39(10^{-6})*AgrValue*Rent - 0.127*Acres.$$

For average-sized contracts, county-level estimates of MC_L in GIP range from \$985 to \$1,790 per acre with a median cost of \$1,390.

Restoration costs are modeled as a function of the agricultural value of the land, the size of the contract, and other variables. The agricultural value is included as an explanatory variable because we believe that landowners would spend more to drain more productive lands and assume that restoration costs are positively correlated with drainage costs.

Approximately 15 percent of the WRP contracts of the GIP report zero restoration costs. Because the dependent variable is truncated, we use the Tobit procedure to estimate the restoration cost function. The Tobit procedure simultaneously estimates the probability that the dependent variable is non-zero and its expected size. Variables of the estimated model are statistically significant and have the expected sign.

The estimated model is used to generate expected restoration costs. By dividing our model's county-level expected cost estimates by contract size, we generate estimates of expected average restoration costs. Costs range from $506 to $602 per acre across counties.

Differentiating the estimated Tobit model with respect to the contract acres generates the expected marginal restoration cost function (MC_R):

$$MC_R = (Z)*(0.888*Rent - 2.12* AgrValue*Rent + 167)$$

where (Z) is the cumulative probability function and Z is the estimated Tobit equation. For average-sized contracts, estimates of MC_R across counties of the GIP range from $101 to $210 per acre.

Senator CARDIN. I would also like to point out that it is my understanding that there has been a lot of discussion about the numeric nutrient standards, that it was the Bush administration's EPA and the EPA Inspector General, the National Academies of Science and the State EPA nutrient task force, led by the Association of States and InterState Water Pollution Control Administrators and the Association of State Drinking Water Administrators all have highlighted the benefits of using a numeric nutrient criteria. I just want to put that in for the record.

Senator BOOZMAN. I think the problem is nobody envisioned the numeric numbers that they would come up with. And I don't disagree that is also a good way of doing things. But it should be that if a State comes up with a plan that makes sense, does what Mr. Werkheiser does, addresses all of the different functions that are going on, if they come up with that plan, they should have the ability to go forward with that as opposed to the EPA talking about collaboration. And yet if they come up with a plan that they say no, they want a numeric thing, which seems to be what we are pushing toward.

Senator CARDIN. I am not so sure there is disagreement on that. As I understand it, we will hear from the Florida people shortly.

Senator BOOZMAN. I think we would agree. That is my problem with it.

Senator CARDIN. I think we all agree on local flexibility, as long as they meet the standards.

Senator BOOZMAN. Reasonable standards based on science..

Senator CARDIN. Reasonable standards based on science. Absolutely. We are in agreement.

We can adjourn the Committee.

[Laughter.]

Senator CARDIN. Any other questions?

Senator SESSIONS. Ms. Stoner, do you know how many agricultural jobs are estimated to be lost in Florida due to the EPA's nutrient rules? If you know?

Ms. STONER. Again, we have asked the National Academies of Sciences to help us evaluate those different cost estimates.

Senator SESSIONS. Well, the Department of Agriculture in Florida estimates it to be 14,500. When issuing the Florida nutrient rule, did you consider the cost associated with that implementation?

Ms. STONER. Sir, the Florida rule is a science-based rule. The implementation is where the costs are considered. And there are a variety of flexibilities that will enable Florida to figure out how to achieve those standards while protecting jobs and reducing costs.

Senator SESSIONS. Well, Florida Department of Agriculture estimates $900 million and $1.6 billion in annual implementation costs just for agricultural land uses. That is a lot of money. Alabama's general fund budget is around $2 billion. This is $1.6 billion. And another study estimated the annual implementation costs as between $450 million and $4 billion.

So I guess all I am saying to you is at a time of job danger in America, we need to consider that as we go forward. I would also note that if you take over the management of these programs around the Country, it is going to stress your budget, even though you have gotten 35 percent increase in 2010. Some of that was stimulus and it is not going to be repeated. Your baseline budget is up 16 percent in the last couple of years. So I would just say that with the budget situation we are in, and the economic situation we are in, I doubt the wisdom of Washington attempting to take over a situation in a State like Florida that has worked real hard to improve its environmental productivity and have a reputation for that.

Thank you, Mr. Chairman.

Senator CARDIN. I don't want to prolong this, I know in the next panel we will probably get into the same discussion. It is my understanding Florida has missed deadlines, though, that were established by the courts. But we will get into that in the next panel. I am not sure how aggressive they have been in dealing with this.

Thank you all very much. We appreciate the panel.

Our second panel, let me introduce them as they come to the witness table. We have Andy Buchsbaum, who is the Great Lakes Supervisor for the National Wildlife Federation. The 20-person staff regional office works with the NWF and other organizations in each of our Great Lakes States.

I am particularly pleased to have a Marylander with us at this hearing, Nick Maravell. Mr. Maravell is a Maryland farmer and a member of USDA National Organic Standards Board. He has farmed organically since 1979. He emphasizes the value added on farm processing and direct marketing. Currently he has 170 acres under cultivation at Nick's Organic Farm in Montgomery and Frederick counties. For the past two decades, Mr. Maravell has conducted on-farm research through grant programs and in cooperation with USDA's Beltsville Agricultural Research Center, University of Maryland and the Department of Agriculture.

I will now turn to Senator Inhofe for an introduction.

Senator INHOFE. Thank you, Mr. Chairman. I am real proud to have Shellie Chard-McClary here. She is a 1992 graduate of the University of Oklahoma, bachelor's degree in chemical engineering and biotechnology. She has 19 years experience implementing the Clean Water Act, the Safe Drinking Water Act and comparable State statutes and operator certification programs. She has served as an officer or on the board of directors of organizations including the Water Environmental Federation, Association of Clean Water Administrators, Association of State Drinking Water Administrators, Groundwater Protection Council and many others. She is a lifelong Oklahoman who knows, I think, a lot more about it than we do. So we are anxious to hear from you.

I will have to say this, though, Shellie, I will have to leave before the conclusion of the second panel. I didn't know the first one would take that long. It is great to have you here.

Senator CARDIN. Welcome. It is nice to have you here.

We also have George Hawkins, who is the General Manager of the D.C. Water and Sewer Authority, a utility providing drinking water delivery and wastewater collection and treatment for a population of more than 600,000 in the District of Columbia, as well as the millions of people who work in the District. D.C. Water also treats wastewater from a population of 1.6 million in Maryland's

Montgomery and Prince Georges Counties, and Virginia's Fairfax and Loudon Counties. We appreciate Mr. Hawkins being here.

We also have Rich Budell. Mr. Budell is Director of the Office of Agricultural Water Policy in Florida's Department of Agriculture and Consumer Services. The office was established to facilitate communications along Federal, State and local agencies and the agricultural industry on agricultural water issues.

We welcome all five of you and we appreciate your patience through the first panel. With that, we will start with Mr. Buchsbaum.

STATEMENT OF ANDY BUCHSBAUM, REGIONAL EXECUTIVE DIRECTOR, GREAT LAKES NATURAL RESOURCES CENTER, NATIONAL WILDLIFE FEDERATION

Mr. BUCHSBAUM. Thank you, Chairman Cardin and members of the Committee. I am Andy Buchsbaum, Regional Executive Director of the National Wildlife Federation's Great Lakes Natural Resources Center. Good afternoon.

I am also the Co-Chair of the Healing Our Waters Great Lakes Coalition, which is a coalition of conservation organizations 110 members strong devoted to protection and restoration of the Great Lakes. NWF also co-chairs other large scale restoration efforts like Chesapeake Bay, the Gulf of Mexico and America's Great Waters Coalition.

I really appreciate the opportunity to testify to you here today. NWF, this is a very important issue for us and our 4 million members and supporters and 47 State affiliated organizations.

Nutrient pollution is so important because our members are sportsmen and sportswomen. They are birders, they are people who love wildlife. And nutrient pollution has caused damage to conservation and recreation and their economic opportunities. You have already heard from the panel how widespread nutrient pollution is, and I am not going to repeat that here. But I do want to give you an example in the Great Lakes, because the statistics you have heard don't capture the story, as Senator Inhofe knows, of what actually happens when you run into an algae bloom or a dead zone.

Today, the National Wildlife Federation issued a report that you have in your packet. The report documents that a nutrient crisis emerging in the Great Lakes is causing massive ecosystem breakdowns. We are seeing, in Lake Erie, for example, the largest toxic algae bloom in recorded history, larger than when Lake Erie was declared dead in the 1960's. The toxic algae that is involved there is called microcystis. It can cause death and illness in animals and people. It has been measured in Lake Erie at levels 1,000 times higher, 1,000 times higher than drinking water standards from the World Health Organization.

We are also seeing algae blooms in Saginaw Bay in Michigan and Green Bay in Wisconsin and on the shores of Lake Michigan. On the shores of Lake Michigan, the algae there combined with invasive species are actually causing botulism outbreaks, botulism, which has killed thousands of fish and birds. This emerging nutrient crisis is affecting people as well. We work closely with charter boat captains throughout the region. One is Captain Rick Unger.

He is the president of the charter boat association for Lake Erie. Captain Unger describes algae that goes for miles along the shores of the lakes and extends miles out into the lakes. It is up to two feet thick, and Senator Inhofe, you can imagine what kind of impact you would have if you swam in that. In some places, it looks like green mud.

This is what Captain Unger says: “The algae is toxic. There are posted warnings: don’t drink the water, don’t touch it, don’t swim in it. People are getting sick out on the water. Captains have respiratory problems.’

Captain Unger’s business has also been badly affected, as you can imagine. Bookings are down, re-bookings are non-existent. The fish have moved. As he says, when the algae moves in, the fish move out. Because his boat has to go much farther to catch fish, his business costs are skyrocketing. It is not just him, it is all the charter boat captains in Lake Erie. In fact, there were 800 such captains last year, this year there are only 700. He expects further decline next year.

Captain Unger finally says, “There are miles and miles where fish can’t live. It is turning back into the 1960’s, when it was called a dead lake.’

This is just one example, and you have heard others, from the Chesapeake to the Gulf, to Long Island Sound. The bottom line here is that it is not just fish and fishing, it is also the fact that it is ducks and geese and hunting. That is where the economics really come in. The American Sportfishing Association reports that all told, there are 456 million anglers in the Country. They generate $45 billion in revenue. But anglers don’t fish where fish go missing and they die.

It is clear that our current management strategies and policies are not getting the job done. We are asking Congress to recognize that fact, and also to keep your foot on the gas. We are not asking for additional regulations or mandates at this time. The existing framework is robust enough. For example, EPA and the States, as you know, are developing nutrient standards, numeric standards in many places, that don’t have a one size fits all mentality. The numeric standards themselves in places like Ohio and Wisconsin vary, depending on the watershed, the stream segment and the needs of the near-shore and the offshore.

The bottom line is the problems at this scale can only be solved with broad partnerships and funding. We ask Congress to continue to increase the funding to address these programs, particularly the Farm Bill, the SRF, State Revolving Loan Fund, Section 319 fund, and of course, the large scale restoration efforts like the Great Lakes Restoration Initiative and the Chesapeake Bay program.

Thank you very much, and I would be happy to answer your questions.

[The prepared statement of Mr. Buchsbaum follows:]

Testimony of Andy Buchsbaum
Regional Executive Director, Great Lakes Natural Resources Center
National Wildlife Federation

Before the
United States Senate
Subcommittee on Water & Wildlife
Nutrient Pollution: An Overview of Nutrient Reduction Approaches
October 4, 2011

Good Afternoon Chairman Cardin, Ranking Member Sessions and Members of the Subcommittee on Water & Wildlife. I am pleased to appear before you today to discuss a topic of great concern to the National Wildlife Federation (NWF) and our 4 million members and supporters nationwide—nutrient pollution. As you know, excessive amounts of nutrients, namely nitrogen and phosphorus, threaten the environmental and economic viability of our nation's waters and the wildlife dependent upon them. Nutrient pollution is one of the most significant threats to waters all across the country. Excess nitrogen and phosphorus from sources such as sewage, animal manure, and fertilizer enter water bodies and have significant negative impacts on water quality. A 2009 report from a task group of senior state and EPA water quality and drinking water officials and managers found that half of U.S. streams have medium to high levels of nitrogen and phosphorus; 78 percent of assessed coastal waters exhibit eutrophication, nitrate drinking water violations have doubled in eight years; and algal blooms are steadily on the rise. Nutrient pollution also impacts almost all of our nation's Great Waters, both coastal and riverine ecosystems including the Chesapeake Bay, Great Lakes, Long Island Sound, Mississippi River, Ohio River, Puget Sound and the Gulf of Mexico. I am pleased that this subcommittee has asked for our thoughts regarding approaches to nutrient reduction in America's waters, but first, I'd like to take a moment to detail NWF's interest and work on this issue.

The National Wildlife Federation is the largest private, nonprofit conservation education and advocacy organization with 47 state and territorial affiliated organizations. Our staff, members, partners and supporters in communities across the country are working to protect and restore wildlife habitat, confront global climate change and connect kids with nature. Our members are sportsmen, outdoor enthusiasts, nature lovers, and others who share a passionate concern for wildlife. And many of our constituents are fisherman, birders, swimmers and boaters, who witness the destructive impact of nutrient pollution each summer as they watch growing dead zones, declining fish stocks, and rivers and streams that have been overrun by algae that can cause sickness and impede many recreational activities.

Our regional offices throughout the country work with local and state governments to protect and restore local rivers, lakes and streams. We co-chair the Healing Our Waters Great Lakes Coalition, the Choose Clean Water Chesapeake Coalition, and the Coastal Louisiana Restoration Coalition. NWF is also a founding member and co-chair of the America's Great Waters Coalition, an alliance of national, regional, state and local organizations joined together to protect, preserve, and restore our nation's Great Waters. Each of these entities works in some capacity to reduce nutrient pollution because it is one of the most common and widespread pollution problems threatening America's aquatic ecosystems.

EPA's most recent National Aquatic Resource Surveys of aquatic health found that 67% of our streams are in poor or fair biological condition, and that of the stressors assessed, nitrogen and phosphorus are the most pervasive in the nation's wadeable streams and lakes. Approximately 50% of streams and more than 40% of lake acres have medium or high levels of nutrients. States have identified more than 15,000 waters nationwide that have been degraded by excess levels of nutrients to the point that they do not meet state water quality standards. This trend threatens some of our nation's most treasured waters. Some of these systems have become so impaired that they are required by the Clean Water Act to implement pollution diets known as Total Maximum Daily Loads. The impact of these ecosystem declines is devastating to wildlife and to those who depend on them. I'd like to illustrate that point by using two of our nation's most important aquatic ecosystems as examples – the Chesapeake Bay and the Great Lakes.

The Chesapeake Bay: A Declining Ecosystem

In the Chesapeake Bay, nutrient pollution is so pervasive that each summer the mainstem of the Bay experiences a dead zone that covers as much as one third of the Bay. Despite efforts to rein it in, it continues to grow. This summer, the Bay experienced an unusually large dead zone, which the Washington Post noted might be the largest in history.[1] These dead zones take many victims from across the tropic scale. The nutrient-related decline of submerged aquatic vegetation has eliminated essential habitat for many fish, shellfish, and other aquatic life. When healthy, this submerged vegetation serves as rich nursery ground, providing food and habitat for juvenile fish. Molting crabs hide from predators in the grass beds. Larger fish such as sea trout, drum, perch, pickerel, and bluefish patrol the grass beds in search of food. Many small and interesting creatures including pipefish, seahorses, mud crabs, spider crabs, and several kinds of shrimp and minnows inhabit the underwater grass beds.

Loss of submerged aquatic vegetation (SAV) has contributed to a substantial reduction in the once massive flocks of waterfowl that darkened the skies of Chesapeake winters. Populations of redhead ducks have declined markedly with the loss of SAV. Other species, such as the Canada goose, American widgeon, and canvasback, have had to change their feeding habits to include other sources of food.

The low oxygen conditions created by excess nutrients have severely impacted life in the Bay. Since 1960, there has been a substantial increase in the amount of Bay bottom with dangerously low levels of dissolved oxygen. Bottom-dwelling, or benthic organisms including worms, clams, oysters, crabs, and many smaller invertebrates are an essential link in the food web. With the decline of these benthic organisms, the entire Chesapeake ecosystem is altered. In fact, a recent study from the University of Maryland found that

[1] "Alarming Dead Zone Grows in the Chesapeake." Darryl Fears. Washington Post. Published July 24, 2011.

the Chesapeake ecosystem had been drastically altered by nutrient pollution over the last 100 years.[2]

As a result, the famous Rockfish fishery has been limited, crabs and oysters are hard to find and beach closures are an annual occurrence. These are just some of the direct impacts of nutrient pollution on aquatic ecosystems, in the Chesapeake and throughout the country. Unless strong action is taken immediately to curb nutrient pollution, this story will continue to repeat itself throughout the country.

Complicating Factors in the Great Lakes

In the Great Lakes, excess nutrients are also causing massive ecological changes. Today, NWF is issuing a report, *Feast and Famine in the Great Lakes: How Nutrients and Invasive Species Interact to Overwhelm Coasts and Starve Offshore Waters*. The report documents the widespread ecosystem breakdowns and the policies and practices needed to address them. (See Exhibit 1). As indicated in the report, excessive nutrients in nearshore waters – in particular phosphorus from both agricultural and point sources – have brought the Great Lakes to a crisis point:

- This summer Lake Erie experienced the worst toxic algal bloom in its recorded history – even worse than the 1960s, when Lake Erie was declared dead.
- Miles of Lake Erie beaches have been closed and algae extends many miles out into the lake with thicknesses of up to 2 feet. Photos of these algal blooms and a satellite photo of their extent are included in this testimony (Exhibit 2).
- Toxic and green algal blooms are common this summer in nearshore areas and embayments throughout the Great Lakes, including Saginaw Bay, Green Bay and the coasts of Lake Michigan.
- Lake Erie is experiencing blooms of mycrosystis, a toxic algae, which has been measured at levels 1,000 times higher than WHO guidelines for drinking water; this algae can cause sickness or even death in humans and animals.

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[2] "Eutrophication of Chesapeake Bay: Historical Trends and Ecological Interactions." W. M. Kempl et al. Vol. 303: 1–29, 2005. Published November 21, 2005.

- We are seeing extensive blooms of the algae Cladophora along Lake Michigan's shores, which have interacted with invasive species to produce outbreaks of botulism poisoning that have killed fish and birds.
- Lake Erie has an anoxic zone where oxygen levels are too low for fish to live that seasonally extends thousands of square miles along the bottom of the lake.

This emerging nutrient crisis is already hurting people and wildlife and damaging the region's economy. NWF's Great Lakes office works closely with charter boat captains in the Great Lakes, particularly those in Lake Erie. Rick Unger, president of the Lake Erie Charter Boat Captains Association reports on terrible conditions on the lake. He says that the algae goes for miles along the beaches and extends miles into the open lake. In some places, the algae is two feet thick and looks like green mud. According to Captain Unger:

> "The algae is toxic. There are posted warnings: Don't drink the water. Don't touch it. Don't swim in it. People are getting sick out on the water. Captains have respiratory problems. The Ohio Department of Public Health is investigating."

In terms of Captain Unger's business, bookings are down; people don't want to go onto the water. Rebookings are nonexistent; once they've been out in the algae they don't want to go back. "When the algae moves in, the fish move out," reports Captain Unger. He says, "The costs of doing business are skyrocketing." He often has to go 10 miles further out to find fish, or 20 miles roundtrip. Gas costs $4.50 a gallon, his boat gets 1 mile per gallon, so that's an extra $90 (20 gallons) every trip.
Last year there were 800 charter boat captains in Lake Erie. This year, there are 700 – they lost 100 in a year. And by next year there will be a lot fewer. Captain Unger says there is no doubt that trend is because of the algae blooms. "There's miles and miles where the fish can't live," he says. "It's turning back into the 1960s, when it was called a dead lake."

This nutrient crisis in the Great Lakes is exacerbated by invasive mussels. Quagga and zebra mussels, now numbering in the trillions in Lake Michigan alone and widespread throughout the Great Lakes, have caused a major ecosystem shift: their efficient filtering capabilities are sequestering much of the nutrients already in or entering lake waters and redirecting them to nearshore and deep bottom waters, reducing availability to other organisms. This phenomenon is encouraging explosive algal blooms in the nearshore while at the same time forming a nutrient desert in offshore waters, contributing to declines in fish populations. For example, Lake Huron has endured a 95% decline in fish biomass in offshore waters of Lake Huron in 15 years and we've seen and 80 percent decline in "primary production" – organisms in the water column that feed fish – in Lake Michigan in the last 25 years (since mid-1980s). In addition, the populations of the tiny freshwater shrimp, Diporiea, that is the base of the Great lakes food web, , have declined in Lake Michigan by 94% in 10 years and in Lake Huron by 57% in 3 years. This is unprecedented: algal blooms caused by excess nutrients and fish population crashes caused by too few nutrients, all happening in the same ecosystem.

Today's *Feast and Famine* report from National Wildlife Federation makes a number of policy recommendations that are included in the policy section of this testimony. I would like to highlight three overarching principles here. First, management actions based on whole-lake objectives alone (or alternatively, focusing on one part of the ecosystem, such as offshore waters) are unlikely to be successful. Controls and management strategies need to take into account the different conditions of nearshore and offshore areas. As part of an overarching lake- or ecosystem-wide management approach, we need to refine management and policy at smaller levels (e.g., sub-basin or watershed) as appropriate. Second, while implementation of policies specific to nutrients and invasive species is critical, we need to explore policies that can address both stresses in an integrated way. For example, if research indicates that an invasive species may be limited in part by nutrients, reductions in nutrient loads could slow its growth and spread while reducing risks of harmful algae blooms. Finally, further nutrient reductions, particularly in targeted watersheds, are essential. Today in the Great Lakes, new nutrient loadings will in many cases continue to feed harmful algal blooms or invasive species, rather than contribute to the growth of desirable fish species.

The Great Lakes and Chesapeake are just two examples of the severity of the nation's nutrient pollution problems. As Captain Unger reports, those problems are causing economic as well as ecological damage. Spending a pleasurable day on the water usually involves at least some expense for travel, equipment and supplies. When multiplied by America's nearly 40 million anglers, their dollars employ millions of people in industries ranging from fishing tackle manufacturing to travel and hospitality to boat manufacturing. Since anglers are found in every state, their expenditures have a significant effect on state and local economies as well.

While many people recognize the recreational and economic benefits of fishing, its significant conservation benefits often go unnoticed. For each fishing-tackle purchase and each gallon of boating fuel consumed, a portion of the money is returned to state fish and wildlife agencies for conservation efforts. America's success in restoring many species of fish and wildlife and protecting natural habitat can largely be credited to the billions of dollars generated by sportsmen and women.

The American Sportfishing Association reports that 45 million anglers generate $45 billion every year in retail sales.[3] A portion of this money goes to licensing and other fees, which are the primary source for improving fish habitat, public access and environmental education.

Sportfishing, and the powerful economic effects it creates, would not be possible without fish. Those same fish would not exist without suitable habitat, which makes clean and healthy rivers, lakes and coastal waters essential to the bottom line. For this reason, NWF urges this committee to do all it can to reduce nutrient pollution in our nation's waters.

Looking Forward and Reducing Nutrient Pollution.

[3] "Sport Fishing in America: An Economic Engine and Conservation Powerhouse." American Sportfishing Association. Revised Edition, January 2008.

Understanding the impact of nutrients on our nation's waters, NWF believes that the federal government has taken some key steps towards remedying this problem and that several others must be considered.

EPA acknowledged the national extent of the nutrient problem, when it issued its 1998 "National Strategy for the Development of Regional Nutrient Criteria." The report reflected an understanding that numeric nutrient criteria can be an effective way to prevent nutrient pollution and to help states comply with the Clean Water Act. EPA encouraged every state to develop numeric nutrient criteria to protect waters from this source of pollution and to help them meet water quality standards under the Clean Water Act. In 2008, an EPA status report found that 19 states have adopted numeric nutrient standards for some or all of their lakes and reservoirs, and 14 states have adopted numeric nutrient standards for some or all of their lakes and streams. We believe that numeric nutrient criteria is the most logical way to ensure ecosystem health in a site specific manner, and urge EPA and Congress to continue to work to ensure that every impaired stream segment, river and lake has a numeric nutrient goal to help restore the ecosystem.

To that end, we applaud the specific EPA actions in Florida and the Chesapeake Bay to promulgate and implement numeric nutrient criteria and we recognize the national significance of these initiatives. A recent article in the Environmental Law Reporter summed this up best, stating, "The CWA, with multiple paths to its destination, is reinventing itself once more. Enacted in modern form in 1972, the next quarter century saw EPA focused on the development of technology standards for industrial and municipal point sources. In the mid-1990s, prodded forward by a stream of citizen suits, the Agency started to address nonpoint sources of pollution through water quality standards and the TMDL program. This movement stalled from 2000-2009 and the current revival raises the question of whether EPA can finally make nonpoint and ambient-based controls effective. The answers are being tested in two venues where the problems are among the most acute and their solutions the most resisted: the Chesapeake

Bay and Florida. *As go the Chesapeake and the Sunshine State, so will go the future of clean water for years to come.*[4]"

The success of EPA's initiative to work with the state of Florida to reduce nutrient pollution may foretell the fate of future generations. If this initiative is further delayed, it could stymie similar efforts throughout the country and ensure the permanent decline of our nation's aquatic ecosystems. If EPA cannot effectively limit nutrients in Florida, a state dependent on recreation and tourism, where the algal blooms are so pervasive that they can be seen from the shores of most rivers and lakes, what chance do other ecosystems have?

In the interest of the Everglades, water quality throughout the state of Florida and all of the waters impaired by nutrients throughout the country, we urge the committee to recognize the importance and necessity of the promulgation of numeric nutrient criteria, in Florida and wherever else nutrient pollution threatens rivers, lakes and streams. We urge you to support the EPA as it works to ensure that all Americans enjoy healthy and pollution free waters.

In addition, NWF recommends that:

- Restoration funding such as the Great Lakes Restoration Initiative, EPA's Chesapeake Bay Program, the Long Island Sound Study and other restoration and pollution reduction programs must be increased and used to intensively target these damaged eutrophic areas with targeted funding to help farmers improve conservation practices and identify the precise vectors and mechanisms that are causing the algal blooms. EPA and other agencies should support an integrated suite of activities, not isolated actions.
- Funding to stop combined sewer overflows and raw sewage overflows is essential. Although not the primary source of nutrient pollution overall, in many

[4] Houck, Oliver A. "The Clean Water Act Returns (Again): Part I, TMDLs and the Chesapeake Bay." Environmental Law Reporter. March, 2011.

places these large wastewater treatment plants have huge and lasting effects, impacts that will get worse as storms continue to worsen. For this reason we urge reauthorization and maximum funding for the Clean Water State Revolving Fund.

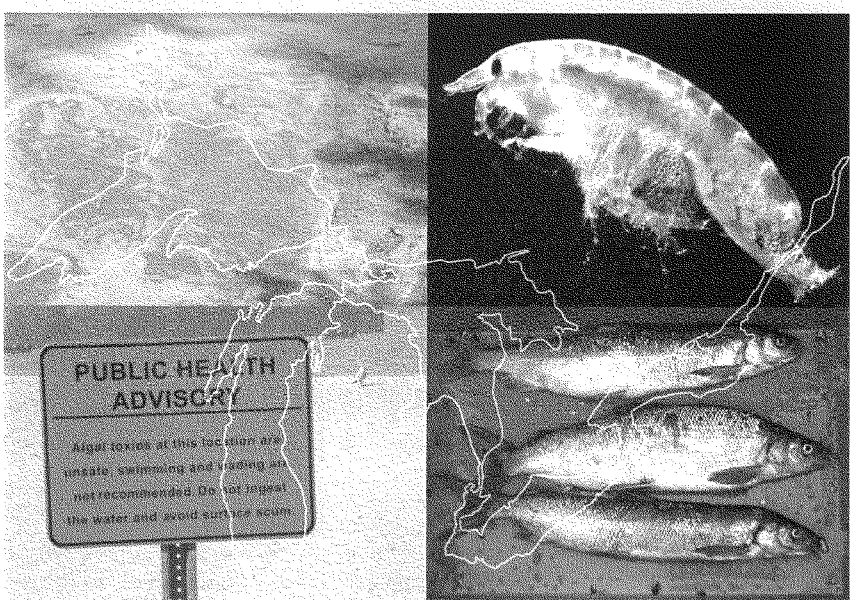
- EPA must do a better job of developing and approving nutrient standards that match the conditions of different waterways and different segments of waterways. A one-size-fits all approach will only cause further damage. A single state-wide nutrient standard will not work; and in many cases, neither will a lakewide nutrient standard. We urge Congress to do all it can to assist states and EPA in promulgating and implementing site specific nutrient reduction targets.
- Farm Bill programs are essential. Most producers will not take their land out of production for essential buffer strips or wetlands if it substantially hurts their bottom line. We need financial incentives to at least cushion the blow. Funding for the conservation title of the Farm Bill is essential. We urge Congress to expand conservation funding in the next Farm Bill and to ensure that these mandatory funds are not capped annually by the Appropriations Committee.
- There needs to be more research. Many of the practices that once reduced nutrient loadings are not working any more, or at least are not working in the same way. For example, no till farming has had strong benefits in reducing sediment transport and runoff. However, in places such as the Lake Erie watershed, we are now seeing less uptake of fertilizers in the soil and higher amounts of soluble reactive phosphorus, a much more damaging form, which might result from those no till practices.
- We need to address drainage and tileage. Extensive tiling means that substantial runoff is never captured by buffer strips, and may bypass wetlands. We need to encourage 2-stage ditches.
- We must address the hypoxic zone in the Gulf of Mexico, our nations' largest deadzone by providing adequate conservation planning and financial assistance to farmers along the Mississippi River and its tributaries.
- Finally, for nutrient standards to be successful in cleaning up America's waters, they must be enforced in the 60% of the nation's waterways that flow intermittently and the wetlands associated with them. These small streams and

associated wetlands do the lion's share of the work in filtering nutrient run-off and storing sediment and floodwaters, yet they are losing Clean Water Act protections and are at increased risk of pollution and destruction in the wake of controversial Supreme Court decisions in 2001 and 2006. We urge the Committee to support efforts to restore Clean Water Act protections to these streams and wetlands.

While these recommendations are not exhaustive, I believe that if enacted, these would make a significant contribution to the reduction of nutrient pollution in our nation's waters and allow the health of their ecosystems to slowly recover. I thank you for the opportunity to discuss this most important issue with you and look forward to answering your questions.

FEAST AND FAMINE IN THE GREAT LAKES

How Nutrients and Invasive Species Interact to Overwhelm the Coasts and Starve Offshore Waters



Feast and Famine in the Great Lakes: How Nutrients and Invasive Species Interact to Overwhelm the Coasts and Starve Offshore Waters

October 2011

Researched and written by Julie Mida Hinderer and Michael W. Murray, Ph.D.
with additional contributions by Trilby Becker

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National Wildlife Federation is solely responsible for the content of this report. The views expressed in this report are those of NWF and do not necessarily represent the views of reviewers or financial supporters.

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EXECUTIVE SUMMARY

The Great Lakes: on the road to recovery, veering close to ecosystem collapse, or both? In fact, recent research indicates the lakes have undergone profound changes over the past two decades, and ongoing changes related to various stressors threaten the ecological health of the lakes in ways unseen since human development in the region began.

In 2005, a team of Great Lakes scientists highlighted the many ongoing stressors facing the lakes, from nutrient pollution to hydrological changes to aquatic invasive species. The report, *Prescription for Great Lakes Ecosystem Protection and Restoration*, warned that the lakes could be facing a tipping point leading to "irreversible ecosystem changes" without urgent actions to address these and other stresses. The report highlighted many instances of Great Lakes "ecosystem breakdown," including dramatic declines in the lower portions of the food web, particularly of a shrimp-like organism (*Diporeia*) in the sediments that served as an important food source for many fish species. Though exact mechanisms are not clear, it appears that the widespread colonization of lake bottoms by invasive mussels has impaired the ability of *Diporeia* and similar organisms to thrive (possibly through changing nutrient cycling), which in turn continues to threaten the well-being of food webs in the Great Lakes.

Six years later, ecosystem problems persist in the lakes, and in some respects have worsened. New research shows that not just *Diporeia* have been decimated across the lakes—so have populations of prey fish (fish consumed by larger predators). For example, in the offshore waters of Lake Huron, **prey fish biomass has declined by 95% in less than 20 years.** Scientists predict similar declines could occur in Lake Michigan. Researchers are still investigating the causes, but one likely factor contributing to widespread ecosystem change is the filtering activity of invasive quagga and zebra mussels. This filtering activity, which removes plankton and other suspended particles (including the nutrient phosphorus) from the water column, results in direct

Great Lakes from MODIS satellite (Photo: J. Schmaltz, MODIS Rapid Response Team, NASA/GSFC) competition for food with other species and has fundamentally altered energy and nutrient flow pathways through the food web. One result is that fish in the offshore such as native lake whitefish and burbot and naturalized Chinook salmon in Lake Huron have steeply diminished in numbers and in health as their prey base is altered.

Lake Erie and nearshore waters in other Great Lakes, however, face the opposite problem: too many nutrients are wreaking a different kind of havoc. Excessive nutrients in nearshore waters—in particular phosphorus from both agricultural and point sources—have caused or contributed to problems such as toxic algal blooms, green algae blooms (including the nuisance alga *Cladophora*), avian botulism, and the Lake Erie central basin "dead zone". Indeed, the summer of 2011 witnessed one of the most extensive harmful algal blooms ever recorded for western Lake Erie, leading to numerous recreational advisories.

How can one part of the Great Lakes (coastal and nearshore areas) be overcome with excessive nutrients while other parts (offshore waters) are deprived of sufficient nutrients? Invasive mussels, now numbering in the trillions in Lake Michigan alone and widespread throughout the Great Lakes, are a likely cause. Zebra and quagga mussels have sufficient filtering capabilities to sequester much of the nutrients already in or entering the lake waters and redirect them to nearshore and deeper bottom waters, reducing availability to other organisms. This phenomenon is encouraging explosive algal blooms in coastal areas and the formation of a nutrient desert in offshore waters, which has contributed to steep declines in fish populations. This is unprecedented: algal blooms caused by too many nutrients, and fish population crashes caused by too few nutrients.

There is no single solution to this ecosystem breakdown. The widespread changes in the Great Lakes nutrient cycle that are causing simultaneous feast and famine require sophisticated responses; one-size-fits-all measures are unlikely to succeed. Three overarching approaches can help address this dichotomy. First, management actions based on whole-lake objectives alone (or alternatively, focusing on one part of the system, such as offshore waters) are unlikely to be successful. Controls and management strategies need to take into account the different conditions of nearshore and offshore areas—as has been recognized to some extent, for example, with different phosphorus targets for western and eastern Lake Erie. In short, as part of an overarching lake- or ecosystem-wide management approach, we need to refine management and policy at smaller levels (e.g., sub-basin or watershed) as appropriate. Second, although implementation of policies specific to nutrients and invasive species (in particular invasive mussels) is critical, we need to explore policies that can address both stresses in an integrated way. For example, if research indicates an invasive species may be limited in part by nutrients, reduction in nutrient loads could slow its growth and spread while also reducing risks of harmful algal blooms. Finally, further nutrient reductions (particularly in targeted watersheds) are essential. Today in the Great Lakes, new nutrient loadings will in many cases continue to feed harmful or nuisance algae, or invasive species, rather than contribute to the growth of desirable fish species. We need to identify and implement measures that promote the growth of native and naturalized species, while minimizing (or ideally avoiding) benefits to nuisance or invasive species.

With these overarching approaches in mind, there are a variety of existing policy frameworks and tools that can help further nutrient reduction efforts, including the following:

- A stronger **Great Lakes Water Quality Agreement**. The current renegotiation of the Agreement offers the opportunity to establish new goals and identify key program targets in the U.S. and Canada in order to address nutrient problems in the lakes. Given new nearshore-offshore dynamics, recognition of the importance of different forms of nutrients (e.g., soluble reactive phosphorus), and inherent natural differences between the lakes, the establishment of different nutrient target concentrations and loads is appropriate for each lake and potentially subwatersheds or basins. In addition, the Agreement should call for establishment of a basin-wide Phosphorus Task Force to research and advise the governments, and the Agreement should propose specific objectives, measurable outcomes, and timetables for achievement of nutrient reduction goals.
- Expanded efforts through **U.S. Farm Bill programs**. Programs such as the Environmental Quality Incentives Program, the Conservation Reserve Program, and Conservation Stewardship Program should be strengthened to further reduce sediment and nutrient exports from agricultural watersheds. Funding for these programs should be maintained and expanded, and the programs themselves should be more targeted. For example, they should use a watershed-based approach to prioritize nutrient reduction efforts directed at both specific sources of nutrients as well as problem areas in tributary and nearshore waters in the region.

- Use of **Clean Water Act tools**, with an increased focus on nutrients. These include revisions to state water quality standards (in particular water quality criteria) for nutrients, as appropriate; consideration of more stringent permit limits for municipal wastewater treatment plants; increased development and implementation of total maximum daily loads for nutrients; and promotion (and adequate funding) of Clean Water Act Section 319 projects targeted, within states, at watersheds prioritized based on nutrient impairments.

Harmful algal bloom near Pelee Island, Lake Erie (Photo: T. Archer, NOAA, Great Lakes Environmental Research Laboratory)

- A special emphasis on **Lake Erie**. This should include strengthening point source and nonpoint source control programs in the watershed, including, revisiting permit limits and enhancing education and outreach efforts on agricultural application of fertilizers.
- Targeted **Great Lakes Restoration Initiative** efforts. GLRI funding should be targeted in ways that emphasize nutrient reduction projects directed at watersheds prioritized based on both sources and nutrient impairments.

Similar efforts are needed on the Canadian side. These include upgrading wastewater treatment plants to reduce nutrient loads, expanding natural vegetation cover in key watersheds, and expanding the scope of and improving best management practices on agricultural lands.

While a number of efforts are needed to address ongoing nutrient problems, it is clear that increased efforts are also needed to **prevent additional major ecosystem changes from aquatic invasive species**. Prevention must be a cornerstone of efforts addressing major vectors, including adopting more stringent ballast water discharge standards, a more aggressive screening and control program for organisms in trade, and strong measures to address canal and waterway transfer of aquatic invasive species (including restoring the hydrological separation between the Mississippi River and Great Lakes Basins in the Chicago area.) In addition, control and eradication measures for species already established must be pursued, including innovative biocontrol measures and fishery management practices that can target species of concern with minimal risk of other negative impacts.

Finally, there is a need for increased activity and funding in two broader areas related to nutrients and invasive species. First, **targeted research and monitoring** efforts are needed, particularly in nearshore areas, as well as improved binational coordination of all aspects of monitoring. Increased research efforts are needed to better understand nutrient dynamics and ongoing ecosystem changes and to help inform resource managers and policy makers addressing these complex changes. Second, **increased education and outreach** efforts are needed to inform the public of problems associated with nutrients and invasive species, along with ways the public can contribute to solutions. These efforts should utilize the numerous existing forums well suited to conduct this work, including agency outreach, university extension, and non-profit programs.

In summary, the Great Lakes are facing feast and famine from invasive species and excessive nutrient pollution. The lakes have faced daunting environmental problems in the past; in the 1960s, Lake Erie was plagued with harmful algal blooms, and many had written it off as beyond revival. However, the concerted efforts of citizens, environmental and conservation advocates, scientists, and policy makers to implement innovative solutions succeeded in restoring the lake. The challenges are no less severe today. While it is clear that further research and monitoring are needed to better understand changes in the nutrient cycle and other lake ecosystem changes, stronger actions are needed now, and we believe a combination of targeted and holistic approaches to address nutrients and invasive species together offers great potential. The lakes remain at a tipping point, and it is time for us to join forces and develop innovative policy solutions to the feast and famine crisis that today plagues the Great Lakes.

SECTION 1

INTRODUCTION

The five North American Great Lakes—Superior, Michigan, Huron, Erie, and Ontario—comprise the largest freshwater system on Earth, containing nearly 20% of the available surface fresh water in the world.[1] This precious natural resource is the ecological, economic, and cultural backbone for a large region of the United States and Canada. The Great Lakes affect the lives of more than 40 million people who live in the basin and depend upon the lakes for drinking water,[2] and the region's population continues to grow. It is estimated that 30% of the population of the Great Lakes states (besides New York) resides in coastal communities.[3]

A diversity of plants and animals also calls the Great Lakes home. This unique freshwater system once supported 180 species of fish unique to the Great Lakes, and today is home to fish such as large- and smallmouth bass, muskellunge, walleye, yellow perch, whitefish, lake trout, and lake sturgeon. The abundant green spaces and forests in the Great Lakes basin provide vital habitat to animals such as moose, wolves, bears, foxes, deer, and bald eagles.[4] The unique coastal ecosystems and wetlands in the region support threatened and endangered birds such as the piping plover and the whooping crane.[5]

The abundant freshwater resources and wildlife of the Great Lakes form the foundation of the region's economy. If it were its own country, The Great Lakes–St. Lawrence River region (encompassing the U.S. and Canada) would be the fourth largest economy in the world.[6] Industries such as manufacturing, shipping, and commercial fishing that depend on the lakes are key components of the regional economy. In the U.S. alone, more than 1.5 million jobs are tied directly to the Great Lakes.[7] Perhaps the most vital contribution of the Great Lakes to the region's economy, however, is their importance to recreation and tourism. The unique beauty of Great Lakes shorelines is showcased through four U.S. National Lakeshores and a National Park,[8] in addition to countless state and local parks and recreation areas across the basin. Recreational fishing in the Great Lakes is worth more than $7 billion annually,[9] and recreational boating creates an economic impact of over $30 billion each year.[10] More than 200,000 jobs in the region are supported by Great Lakes recreation and tourism.[11]

A healthy Great Lakes ecosystem is vital to sustain and promote the wealth of recreational opportunities in the region. Water quality and wildlife must be protected, restored and enhanced to support tourism, economic growth, and other benefits provided by the lakes. There is a long history of cooperative efforts in the U.S. and Canada to protect and restore the Great Lakes, as summarized in Section 5. Coordination was enhanced on the U.S. side in 2005, when federal agencies, governments of the eight Great Lakes states, tribes, industry and nongovernmental organizations recognized the need for a coordinated restoration effort and joined forces to create a shared vision for the lakes under the Great Lakes Regional Collaboration (GLRC) Strategy.[12] Through the creation of the *GLRC Strategy*, the region showed that it was ready to invest in projects that would directly advance common restoration goals. In response, the federal government created the Great Lakes Restoration Initiative (GLRI), a five-year investment that included $475 million for restoration and protection programs in its first year.

So far, the GLRI has funded numerous projects across the basin that are restoring wildlife habitats, cleaning up beaches, and educating the public on invasive species, to name a few.[13] In addition to ecological benefits, the GLRI is providing an economic boost to the region: the Brookings Institution estimates that for every $1 invested in Great Lakes restoration, $2 of economic benefit are produced.[14]

Despite this progress towards healthier Great Lakes, ecological problems remain that threaten to stall or even reverse this progress. Major threats to the lakes were highlighted in a 2005 report which noted that stresses such as invasive species, hydrologic alterations, land use changes, and nutrient loadings could interact to cause "ecosystem breakdown" in the Great Lakes, whereby resiliency is overcome and the ecosystem is pushed into a new state.[15] Among the most severe of these problems are nutrients—with too much in some places, and too little in others. Excessive nutrients sicken the Great Lakes in nearshore areas by causing toxic algal blooms in shallow areas and oxygen-poor "dead zones" on lake bottoms. This serious problem, which first appeared in the mid-1900s, has returned with a vengeance. Another dire problem facing the Great Lakes is invasive species. Currently, non-native mussels are wiping out food webs in offshore areas of the lakes, turning once-productive waters with a diversity of life into lake monocultures dominated by invasive mussels. These invasive mussels are also concentrating nutrients in nearshore waters (typically defined as waters out to about 30–100 feet depth), further exacerbating algal blooms. Thus, while harmful algae in the nearshore are feasting on excess nutrients, fish populations in deep waters are fighting famine. This dangerous dichotomy requires urgent and drastic action to restore balance to the Great Lakes.

Freighter on Muskegon Channel, Lake Michigan (Photo: NOAA, Great Lakes Environmental Research Laboratory)

SECTION 2

BACK FROM THE BRINK
Historical Nutrient Pollution and Recovery in the Great Lakes

Since European settlement, all five of the Great Lakes have progressed toward slightly more biologically productive, or eutrophic, conditions (see Box 1).[23] In the 1950s and 1960s, however, rapid and dramatic eutrophication occurred in many areas of the lakes due to human inputs of nutrients. This phenomenon, known as "cultural eutrophication," was caused by excessive watershed inputs (or **loading**) of phosphorus from human activities. Some phosphorus pollution was dumped directly into the lakes or their tributaries via "point sources" such as outflows from wastewater treatment plants and storm sewers. Excessive phosphorus loading also came from "nonpoint" sources such as fertilizer-rich runoff from agricultural fields (See Figure 1).[24]

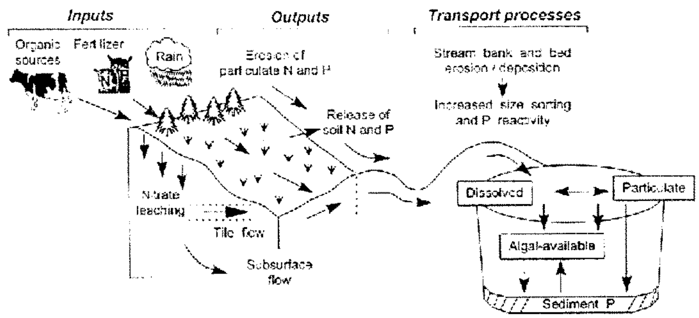


FIGURE 1. Inputs and outputs of phosphorus (P) and nitrogen (N) from agricultural land, and transport processes into lakes. (Reproduced with permission of ECOLOGICAL SOCIETY OF AMERICA, from Carpenter, S.R., et al. 1998. Nonpoint pollution of surface waters with phosphorus and nitrogen. Ecological Applications 8 (3), 559-568; permission conveyed through Copyright Clearance Center, Inc.)

Perhaps the most dramatic symptoms of cultural eutrophication in the Great Lakes during this period were large, harmful blooms of algae, particularly blue-green algae. These harmful algal blooms cause unpleasant drinking water taste and odor and can produce toxins dangerous to humans and wildlife.[25] Large mats of a filamentous green alga, *Cladophora*, also reached nuisance levels in many areas of the Great Lakes in the mid-1900s,[26] fouling beaches and impacting recreation. Harmful algal blooms were particularly severe in lakes Erie and Ontario, which were more eutrophic than the upper lakes, but they also affected areas of lakes Michigan and Huron such as Saginaw Bay and Green Bay.[27] In addition to impacts to beaches and human health, another consequence of massive algal blooms is **hypoxia.** When large amounts of algae die and settle to the lake bottom after a bloom, decomposition increases, consuming available oxygen. This leads to oxygen-poor bottom waters that are unable to support most forms of life—hence the term "dead zones" commonly used to describe hypoxic areas. Hypoxia can lead to fish kills and over time decreases biodiversity in eutrophic lakes.[28] At the peak of cultural eutrophication, 70% of central Lake Erie's bottom waters suffered from pronounced hypoxia, negatively affecting benthic (bottom-dwelling) organisms and fish.[29]

Community structure of phytoplankton (floating plants or algae, see Box 2) also shifted in response to increased nutrient loading and eutrophication in the Great Lakes. In Lake Erie, a major increase in blue-green

BOX 1: TROPHIC STATES

The five Great Lakes historically vary in their "**trophic states**." A body of water's trophic state represents its biological productivity, which is primarily controlled by the availability of nutrients such as phosphorus and nitrogen.[16] These nutrients limit **primary production**, which is the growth of phytoplankton and other plants (often assessed by measuring the amount of **chlorophyll *a*** in the water). In the Great Lakes, phosphorus is the nutrient that limits biological activity under most conditions.[17] Primary production in turn limits **secondary production** at higher **trophic levels**, or higher levels of the food web, such as fish. Thus, lakes with fewer nutrients will be less productive overall, or at lower trophic states, than those with more nutrients.

In general, lakes are classified using three trophic states: oligotrophic, mesotrophic, or eutrophic. **Oligotrophic** lakes (such as Lake Superior) have very low nutrient concentrations and thus low primary productivity. Water in oligotrophic lakes is very clear. **Mesotrophic** lakes are more productive than oligotrophic lakes, and have moderately clear water. **Eutrophic** lakes (such as Lake Erie) have the highest concentrations of nutrients and thus the most productivity. The dense growth of phytoplankton in eutrophic lakes causes their water to be murkier. The algae community in eutrophic lakes tends to have a larger abundance (especially in warmer months) of **blue-green algae** (more formally cyanobacteria), which can sometimes produce toxins. These three trophic state classifications are useful, but in reality, lakes fall along a continuous spectrum of productivity; thus, they can be described using terms such as "ultra-oligotrophic," "meso-eutrophic," or "hyper-eutrophic."[18]

In the absence of human influences, the physical qualities of the Great Lakes (such as their depth, temperature, and geologic setting) and the characteristics of their watersheds determined their trophic state. Deep, cold lakes such as Lake Superior and Lake Huron were historically oligotrophic.[19] Lake Erie, on the other hand, is much warmer and shallower and as a result is more productive (even in the absence of human activities).[20] Of course, the Great Lakes are complex bodies of water with distinct basins and embayments that often have different trophic states than their open waters. For example, Lake Huron's Saginaw Bay tends towards mesotrophic or even eutrophic conditions, even though most of the lake is oligotrophic.[21] Similarly, nearshore waters of lakes Michigan, Erie, and Ontario tend to be more eutrophic than offshore areas.[22]

BOX 2: GREAT LAKES FOOD WEBS

To appreciate the scope of recent changes in Great Lakes food webs and nutrient dynamics, it is important to understand the structure of food webs and their historic conditions. Prior to major species invasions, the Great Lakes **pelagic** (open water) fish community was dominated by lake trout and burbot – piscivorous predators (fish that prey upon other fish) that fed in deep waters on small **forage** (or prey) fishes such as lake herring, deepwater ciscoes, and bloaters.[30] In shallower, nearshore areas of the Great Lakes, the fish community was dominated by smallmouth and largemouth bass, muskellunge, northern pike, walleye, yellow perch, and smaller fishes such as emerald and spottail shiners.[31]

At the base of historic food webs, fish production has historically been supported by large populations of **benthic macroinvertebrates** (small, bottom-dwelling crustaceans and insects), dominated by the amphipod *Diporeia*.[32] *Diporeia* was vital to the diets of many fish species and was preyed upon by most Great Lakes fishes at some point in their life cycle.[33] Pelagic forage fishes also graze on **zooplankton** (tiny animals that swim in the water column) that in turn feed on **phytoplankton** (microscopic floating plants).

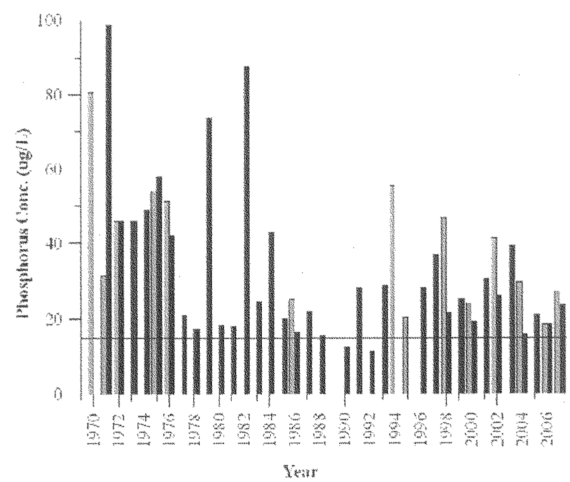
algae, which are well-suited to eutrophic conditions, occurred.[34] Changes in benthic communities also occurred in response to eutrophication. Declines in water and sediment quality in western Lake Erie caused populations of the mayfly *Hexagenia*, once the most dominant benthic invertebrate, to disappear beginning in the late 1950s.[35]

The serious ecological and economic impacts of cultural eutrophication were well-documented by the scientific community in the 1960s, and the media brought the issue to the public's attention. In response, the governments of the U.S. and Canada signed the landmark Great Lakes Water Quality Agreement (GLWQA) in 1972. In the agreement, the two countries pledged to solve the eutrophication problem by reducing loads of the nutrient phosphorus to the lakes, primarily through controls of point sources such as discharges from wastewater treatment plants. In addition, both the U.S. and Canada passed federal legislation and formed new agencies to implement and enforce environmental laws protecting water quality. Phase-outs and bans on phosphorus in laundry detergents were enacted by the federal government in Canada and by individual U.S. municipalities and states in the 1970s and 1980s. Revisions to the GLWQA in 1978 recognized the importance of nonpoint sources of nutrient loading and the need for programs (such as addressing agricultural practices and urban runoff) to address these sources.[36] (For more information on policy efforts to reduce phosphorus pollution, see Section 5.)

The efforts of the U.S. and Canadian governments to curb nutrient pollution paid off: the phosphorus reduction programs generally worked and the subsequent reversal of cultural eutrophication in the Great Lakes became a great environmental success story. As a result of loading reduction programs, phosphorus loadings decreased across the basin.[37] Target phosphorus loads were achieved in lakes Superior, Huron, Michigan, and Ontario by the early 1980s[38] and in Lake Erie by the mid-1980s.[39] In response to reduced phosphorus loadings, concentrations of phosphorus in open waters declined, particularly in lakes Erie and Ontario where conditions were more eutrophic.[40] In Lake Erie, target phosphorus concentrations were reached by the early 1990s in all three basins, although concentrations were quite variable and exceeded targets in some years (see data for western Lake Erie in Figure 2 below).[41] Episodes of hypoxia in Lake Erie's bottom waters were reduced.[42]

Great Lakes food webs recovered following reductions in nutrient loadings. Gradual oligotrophication (lake wide declines in primary production by algae) occurred in lakes Michigan, Huron, and Ontario following the implementation of stricter phosphorus controls,[43] with Lake Ontario reaching an oligotrophic state by the early 1990s.[44] Chlorophyll concentrations declined in all three basins of Lake Erie following phosphorus load reductions,[45] and by 1992 primary productivity in the lake indicated a shift from eutrophy to meso-oligotrophy.[46] Declines in abundance of blue-green algae led to improved drinking water taste and odor[47] and decreases in phosphorus loading were successful in reducing blooms of the harmful alga *Cladophora* throughout the lakes.[48] In lakes Erie and Ontario, shifts in phytoplankton and zooplankton communities indicated a movement away from eutrophic conditions.[49] In western Lake Erie, the burrowing mayfly *Hexagenia* made a comeback after populations had disappeared due to eutrophication.[50] Impacted fish communities rebounded as well; in Lake Erie, the reduction in phosphorus loading contributed to the revival of walleye populations[51] and improved overall fish community diversity.[52] In general, the scientific and policy communities agree that the GLWQA and programs through federal laws such as the Clean Water Act were successful in meeting the goal of halting and reversing eutrophication in the Great Lakes in the 1970s.

FIGURE 2
Trends in total phosphorus concentrations (ug/L) in western Lake Erie from 1970-2007. Darker bars indicate U.S. data, lighter bars Canadian data. Horizontal line represents target as established in the Great Lakes Water Quality Agreement. (Adapted with permission from Environment Canada and U.S. EPA. 2009. Phosphorus Concentrations and Loadings – Indicator #111. State of the Great Lakes 2009. Cat. No.En161-3/1-2009E-PDF, pp. 77-81.)



SECTION 3

ONGOING ECOSYSTEM SHOCK

Invasive Species in the Great Lakes

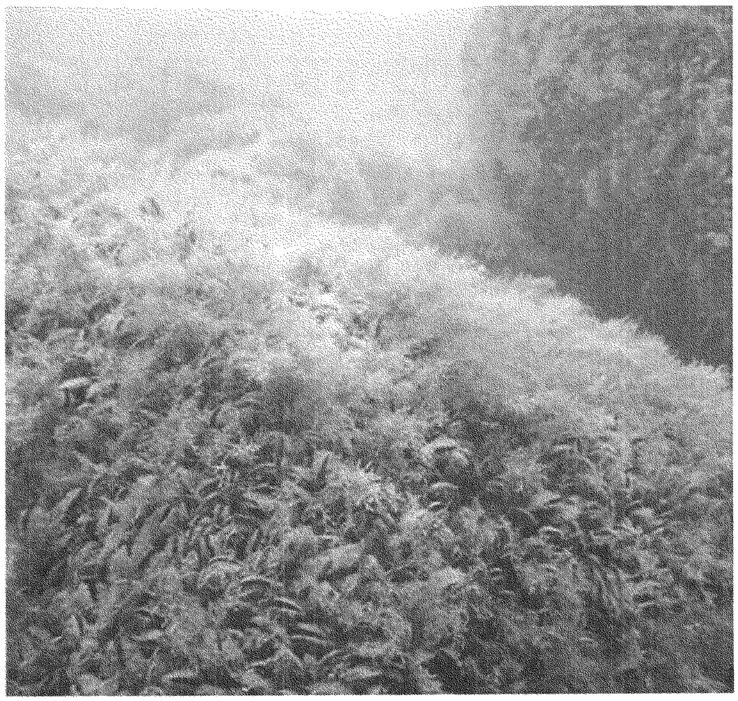
Even before excess nutrient loading caused cultural eutrophication across the Great Lakes, humans were polluting the ecosystem in another way: through the introduction of non-native species.[53] This section details two chapters in the history of invasive species in the Great Lakes: top-down food web changes caused by several invasive species that affected fish communities, and bottom-up shifts caused by invaders that have altered the base of the food web. It is important to note that in analyzing some food web changes, it is difficult to separate the effects of reduced nutrient loading from the impacts of invasive species because these changes were occurring simultaneously.[54]

Early invasions alter the fish community

Great lakes fish communities have undergone many drastic changes since human settlement of the region. Fish populations in particular were heavily impacted by several non-native species introductions that began in the mid- to late 1800s. The invasion of the sea lamprey, a species present in Lake Ontario as early as 1835 (and possibly native to the lake) that spread to Lake Erie by 1921, likely had the greatest impact on fish populations.[55] Sea lampreys are parasitic, eel-like fishes that attach to other fish and feed on their blood and bodily fluids; one adult sea lamprey can kill up to 40 pounds of fish in as little as a year. Sea lamprey predation, combined with commercial overharvesting (and in some cases other factors such as toxic contaminants[56]), led to the collapse of populations of native lake trout, burbot, and lake whitefish in the mid-1900s.[57]

The decline in abundance of top predators allowed populations of the alewife—a small, invasive forage fish that eats zooplankton—to grow unchecked. Alewives, native to the Atlantic coast of the United States, probably invaded the Great Lakes through the Erie Canal and were common in Lake Ontario by 1873, although some scientists believe they were native to that lake.[58] The opening of the Welland Canal between Lake Ontario and Lake Erie in 1829 allowed alewives to invade the rest of the Great Lakes, and they spread to Lake Superior by 1954.[59] Following the collapse of lake trout that preyed upon alewives, their abundance increased dramatically in lakes Michigan and Huron; these large populations of alewives and rainbow smelt, another introduced species, caused declines in native prey fishes such as lake herring and deepwater ciscoes.[60] Massive alewife die-offs in the 1960s resulted in carcasses washing ashore in huge numbers, impacting recreational activities.[61] In response to the alewife explosion, large-scale stocking of salmonids such as Coho and Chinook salmon was initiated in the 1960s to control nuisance levels of alewives and to establish a sport fishery.[62] These efforts were largely successful, leveling off alewife populations and launching a successful recreational fishery centered on introduced salmon.[63] In general, Great Lakes offshore fish communities have shifted from being dominated by deep-dwelling piscivores (e.g., lake trout) and native forage fishes (e.g., lake herring) to communities often dominated by introduced species that inhabit shallower waters.[64]

Although many nearshore areas of the Great Lakes still support strong recreational fisheries,[65] fish communities in the nearshore have also been impacted by invasive species. Alewife interference with reproduction was blamed for declines in populations of walleye and yellow perch between the 1950s and 1970s.[66] The invasive round goby, first discovered in the Great Lakes in 1990,[67] is an aggressive bottom-dwelling fish that can tolerate a wide range of environmental conditions, eat a variety of foods including invasive mussels, and spawn prolifically.[68] Round gobies have the potential to negatively impact native fish species by competing for food and habitat and interfering with reproduction; for example, gobies were blamed for the local extirpation of the mottled sculpin in Calumet Harbor, Lake Michigan.[69] The Eurasian ruffe, an invasive perch-like



Quagga mussels and nuisance algae *Cladophora* in western Lake Michigan (Photo: H. Bootsma, University of Wisconsin-Milwaukee)

fish, was found in Lake Superior in 1986 and rapidly became the most abundant fish in the St. Louis River estuary.[70] Since its introduction, the ruffe has become established in parts of Lake Michigan (Green Bay) and Lake Huron (Thunder Bay).[71] If the Eurasian ruffe becomes established in Lake Erie, it could have disastrous impacts on economically important walleye and perch fisheries.[72]

Dreissenid mussels re-engineer the Great Lakes ecosystem

Perhaps no other invasive species have had more impact on the Great Lakes ecosystem than zebra and quagga mussels.[73] The zebra mussel (*Dreissena polymorpha*) and its relative the quagga mussel (*Dreissena rostriformis bugensis*), hereafter collectively referred to as dreissenids, were introduced into the Great Lakes via ballast water from oceangoing freighters in the late 1980s.[74] Zebra mussels are well-suited to colonize nearshore areas and did so in great numbers, impacting industries, recreational activities and municipal water supplies and causing billions of dollars of damage. The quagga mussel can tolerate and reproduce in colder temperatures, and is better able to inhabit softer bottom sediments than its cousin, so it is better suited to proliferate in deeper, offshore waters.[75] Quagga mussels have replaced zebra mussels as the dominant dreissenid in many areas of the Great Lakes, and their populations continue to explode in deep areas of lakes Michigan, Huron, and Ontario.[76] By one estimate, there are over 950 trillion quaggas in Lake Michigan alone.[77]

Invasive dreissenid mussels impact the Great Lakes ecosystem via several mechanisms. With their large populations and ability to filter water at volumes and rates much greater than native grazers,[78] dreissenids can significantly decrease phytoplankton abundance and thus primary productivity.[79] This filtration can lead to drastic increases in water clarity,[80] a change that — while often welcomed by humans who use the Great Lakes — can have serious implications for the ecosystem (discussed in more detail below). In addition to influencing algal primary production, dreissenid mussel filtering and waste-producing processes have significantly altered nutrient cycling and dynamics in large areas of the Great Lakes.[81] Although dreissenids can increase the availability of nitrogen in the environment,[82] their impacts on phosphorus dynamics are of more interest because phosphorus is usually the limiting factor for algal growth in the Great Lakes.[83] Depending on environmental conditions such as existing nutrient levels in the water column, dreissenids can sometimes retain phosphorus and nitrogen in their tissues at relatively constant concentrations[84] and can therefore reduce open-water phosphorus concentrations.[85] Given their huge populations, large quantities of phosphorus are locked in dreissenid tissues, with some permanently sequestered in the shells of dead mussels.[86] Recent research suggests that up to two-thirds of the entire phosphorus inventory in Lake Michigan is tied up in quagga mussels.[87] Environment Canada and the U.S. Environmental Protection Agency (EPA) report that current offshore phosphorus concentrations in lakes Michigan, Huron, and Ontario may be too low to support healthy levels of biological productivity.[88] As discussed more fully below, however, in shallower nearshore areas dreissenids tend to regenerate soluble forms of the nutrient through excretion and waste egestion, making usable forms more available in the water column.[89] Direct filtration, increased water clarity, and changes to nutrient dynamics all contribute to food web impacts of dreissenid grazing.[90]

The dual tendencies of dreissenids in processing phosphorus have caused startlingly different impacts in nearshore and open waters of the Great Lakes. On a large scale, zebra and quagga mussels have re-engineered nutrient cycling in large areas of the Great Lakes to the extent that phosphorus is trapped in nearshore and benthic zones, depriving offshore areas (see Figure 3).[91] This hypothesized mechanism, known as the "nearshore phosphorus shunt," may encourage the growth of blooms of harmful algae such as *Cladophora*,[92] and could be largely to blame for the feast/famine imbalance currently seen in the Great Lakes. Recent research supporting the existence of the phosphorus shunt implicates dreissenid mussels in decreasing the amount of phosphorus exported from Saginaw Bay to the open waters of Lake Huron by 60%.[93] Bottom-dwelling algae species and other benthic plants favored by this phosphorus shunt may further benefit from increased water clarity due to dreissenid filtering.[94] In addition, dreissenid mussels appear to selectively reject certain toxin-producing species of the blue-green algae *Microcystis*, enabling these bloom-forming species to dominate algae assemblages.[95] Ratios of nutrients excreted by dreissenids also can cause community shifts towards blue-green algae,[96] further encouraging harmful blooms. Another invasive species, the round goby, might amplify the shunt of phosphorus to the nearshore by serving as an energy and nutrients link between dreissenid mussels and nearshore fish, given the propensity of round gobies to feed on the invasive mussels. While this phenomenon potentially benefits nearshore species such as smallmouth bass, it occurs at the expense of offshore fishes.[97]

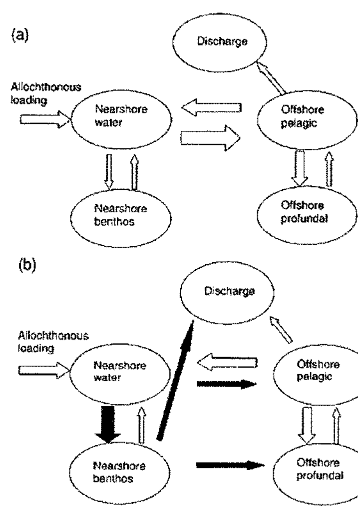


FIGURE 3
Hypothesized nearshore phosphorus shunt diagram showing transport of phosphorus between nearshore and offshore waters a) before dreissenid mussel invasion and b) after dreissenid mussel invasion Shaded arrows represent the most altered fluxes; arrow width indicates relative size of flux. Note that "allochthonous" refers to loads from external sources to the lake, and "discharge" refers to transport of phosphorus out of the lake system (e.g., out of Lake Erie through the Niagara River). (©2008 Canadian Science Publishing or its licensors. Reproduced with permission from Hecky, R.E., et al. 2004. The nearshore phosphorus shunt: A consequence of ecosystem engineering by dreissenids in the Laurentian Great Lakes. Canadian Journal of Fisheries and Aquatic Sciences 61 (7), 1285-1293.)

BOX 3: OTHER PRESSURES ON GREAT LAKES FOOD WEBS

In addition to impacts on nutrient dynamics and food webs discussed in this section, dreissenid mussels impact the Great Lakes ecosystem in numerous other ways. They can serve as "physical ecosystem engineers," altering the structure of the lakebed and impacting habitats for other species.[116] Dreissenids can attach to the shells of native mussels, which has caused extirpation of the latter in many areas of the Great Lakes.[117] Dreissenids are also implicated in a phenomenon known as "invasional meltdown," whereby they facilitate the invasion of other species; for example, dreissenids created better conditions for the round goby to establish and proliferate.[118] Zebra and quagga mussels have become integrated into food webs in some areas of the Great Lakes, altering pathways for the transfer of energy, nutrients, and contaminants to higher trophic levels. In some cases, native species such as smallmouth bass and whitefish can benefit indirectly from this integration of invasive dreissenids into food webs;[119] overall, however, the invasion of dreissenids has resulted in declines in the condition of Great Lakes fishes.[120] Invasive mussels and round gobies are also implicated in outbreaks of botulism that kill wildlife, discussed in more detail in Section 4.

While invasive dreissenids alter nutrient cycling and reduce primary production, Great Lakes food webs are also changing in response to other drivers. Large invasive, predatory zooplankton such as the fishhook waterflea (*Cercopagis pengoi*) and the spiny waterflea (*Bythotrephes longimanus*) are placing additional pressure on food webs. *Cercopagis* has impacted the Lake Ontario food web through predation pressure and by shifting zooplankton spatial distribution.[121] In lakes Michigan, Huron, and Erie, the invasion of *Bythotrephes* has caused drastic declines in the abundance of some zooplankton species and a decrease in overall species diversity.[122] In Lake Huron, consumption of zooplankton by *Bythotrephes* can exceed that due to fish and the opossum shrimp (*Mysis diluviana*) combined; the latter is an important food source for a number of fish species.[123] Both *Bythotrephes* and *Cercopagis* are implicated in recent declines in populations of *Mysis* in Lake Ontario.[124] Whereas historical Great Lakes zooplankton communities were dominated by herbivorous species that fed mostly on phytoplankton,[125] invasive predatory cladocerans, which are not a good food resource for fish, compete with fish and native invertebrates for zooplankton resources and are clearly capable of altering food webs.

Invasive species also have the potential to place pressure on Great Lakes food webs via wetlands. Coastal wetlands are being invaded by plants such as the common reed (*Phragmites australis*),[126] reed canary grass (*Phalaris arundinacea*),[127] purple loosestrife (*Lythrum salicaria*),[128] and curly pondweed (*Potamogeton crispus*)[129] that crowd out native plants and decrease the quality and availability of habitat for wildlife. Great Lakes coastal wetlands are important to the health of food webs, serving as crucial habitat for many fish species during early stages of their life cycles.[130] Some of these invasive plant species can even alter the function of the wetlands themselves; for example, *Phragmites* can "dry up" areas it invades.[131] Curly pondweed can increase phosphorus concentrations in surrounding waters, encouraging nearshore algal blooms.[132] Currently, according to Environment Canada and the U.S. EPA, coastal wetland plant communities are in only "fair" condition in lakes Michigan, Huron, and Erie, with Lake Erie's status deteriorating. Lake Ontario's coastal wetland communities are deemed to be in "poor" status.[133] If coastal wetlands continue to be lost and degraded due to invasive species and other human-induced stressors, Great Lakes food webs will be further impacted.

The ability of dreissenids to consume large quantities of phytoplankton, and to alter nutrient cycling, has had major impacts on both nearshore and offshore food webs. Dreissenid mussels are implicated in the collapse of the benthic amphipod *Diporeia* across the lakes, although exact causal mechanisms are unclear.[98] Populations of *Diporeia*, once a vital part of the diets of many Great Lakes offshore fishes and more than 70% of benthic biomass in deep parts of the Great Lakes,[99] have all but disappeared in shallow areas of lakes Michigan, Huron, and Ontario and are extremely depressed in deeper offshore zones.[100] *Diporeia* now appears to be completely absent from Lake Erie.[101] It is hypothesized that dreissenid filtering may cause food limitation in *Diporeia*, which relies on phytoplankton blooms settling to the lake bottom.[102] Another theory is that mussel waste products are toxic to *Diporeia*.[103] Declines in populations of other benthic invertebrates, while likely partially due to decreased nutrient loads, are also linked to the invasion of dreissenid mussels.[104] Changes in the benthic community, in particular the disappearance of *Diporeia*, have already begun to impact fish populations. Declines in the condition of fishes such as alewives,[105] deepwater sculpin,[106] and the commercially important lake whitefish[107] have been observed.

While the symptoms of nutrient pollution and dreissenid ecosystem engineering are manifested by the increased prevalence of harmful algal blooms in the nearshore (see Section 4), the picture is much different in offshore regions of the Great Lakes. Quagga mussel filtering caused dramatic reductions in spring primary production in the offshore regions of lakes Michigan and Huron beginning in the early to mid-2000s when this species became abundant in this region (see Plot 4, pg. 19).[108] Although gradual, long-term oligotrophication resulting from nutrient controls was anticipated,[109] this rapid oligotrophication in response to dreissenids has taken the scientific community by surprise. The spring diatom bloom has all but disappeared and the pelagic zones of lakes Michigan and Huron now resemble ultra-oligotrophic Lake Superior.[110] The zooplankton community, which once relied on the spring diatom bloom as an important food source, has responded with drastic declines in abundance and shifts in community structure.[111] As the foundations of the Great Lakes food web are eroded, fish communities are unable to sustain themselves. In Lake Huron, populations of deepwater prey fishes, including bloaters, sculpin, and smelt, have dramatically declined (see Plot 5, pg. 19),[112] contributing to the collapse of populations of Chinook salmon, an important sport fish.[113]

Although the impacts of dreissenid mussels on nutrient dynamics, primary production, and food webs are not yet fully understood, it is clear that these invasive organisms have caused a significant, and perhaps permanent, ecosystem shift in the Great Lakes. As described previously, dreissenids have shifted energy, nutrients, and production to benthic and nearshore areas of the Great Lakes.[114] Research also indicates that invasive mussels have "decoupled" the relationship between total phosphorus loads and chlorophyll (a proxy for primary production).[115] Thus, changes in phosphorus loading in Great Lakes waters may no longer result in a predictable, corresponding response from algae populations throughout the lakes. This alteration of the phosphorus-chlorophyll relationship, driven by invasive dreissenid mussels, further explains how Great Lakes offshore food webs can be collapsing in response to reduced primary production and nutrient depravation even while nearshore areas show symptoms of eutrophication.

These breakdowns are made worse by the incredibly fast rate at which dreissenids are driving ecosystem change. In the past, changes such as cultural eutrophication from nutrient pollution took decades to manifest; now, we are seeing dramatic alterations of the Great Lakes food web occurring in the space of several years. If these rapid ecosystem changes caused by dreissenids were not enough, other invasive species (including predatory zooplankton) have also been affecting food webs in the Great Lakes (see Box 3). In addition to these ecosystem changes, invasive species are having both direct and indirect effects on the region's economy (see Box 4).

BOX 4: ECONOMIC IMPACTS OF DREISSENID-DRIVEN FOOD WEB CHANGES

In addition to their serious ecological impacts, zebra and quagga mussels have had major economic consequences in the Great Lakes. The invasive mussels clog water intake pipes in huge numbers, impacting power plants, municipal water suppliers, and other users.[134] Between 1993 and 1999, zebra mussels are estimated to have cost the power industry in the U.S. $3.1 billion, and significant impacts to other sectors have also been seen.[135] Zebra mussels have also impacted recreation and tourism around the Great Lakes basin, fouling boats and docks and washing up on beaches in huge numbers.[136] A recent study estimated losses to the region associated with ship-borne invasive species broadly to be at least $200 million annually.[137]

The indirect economic effects of dreissenid mussel invasion may be even more severe than the direct impacts to infrastructure and beaches. Food web changes (likely caused in large part by dreissenid filtering) contributed to the collapse of the Lake Huron Chinook salmon fishery in the mid-2000s. Coastal communities and businesses such as charter boat companies and tackle shops around the Lake Huron basin were hit hard by the loss of this important fishery. The Michigan Department of Natural Resources estimates that 10 ports in Michigan alone have lost more than $19 million annually since 2004 as a direct result of the Chinook salmon collapse.[138] Fishery scientists are beginning to see warning signs that a similar Chinook salmon collapse could occur in Lake Michigan, and managers are seeking ways to manage effects of a declining forage base. The economic ramifications of a salmon collapse on Lake Michigan would be severe: in 2009 alone, the fishery brought over $32 million to coastal communities around the lake.[139]

SECTION 4

EUTROPHICATION RELAPSE

Current Nutrient and Water Quality Trends and Issues

Despite the success of phosphorus control programs under the GLWQA and federal legislation, changes such as the invasion of dreissenid mussels and their re-engineering of nutrient dynamics have resulted in recent declines in nearshore water quality in the Great Lakes. Indicators suggest that some areas of the Great Lakes might be slipping back towards the eutrophication problems of the 1960s and 1970s due to both point and nonpoint sources of phosphorus pollution.

As previously discussed, GLWQA target phosphorus loads had been met across the lakes by the mid-1980s. Between 1996 and 2002, the Lake Erie target load was met in most years, except in 1997 and 1998 when tributary loads increased due to heavy precipitation.[140] In recent years, however, phosphorus loads to some areas appear to be increasing after a long period of overall decline.[141] Although target phosphorus loads continue to be met consistently for the open waters of lakes Superior, Michigan, and Huron, recent loads exceed targets in some historically eutrophic areas of those lakes such as Green Bay and Saginaw Bay.[142] In lakes Erie and Ontario, inter-annual variability in loading is high and targets are not being met every year (see Figure 4).[143] As discussed below, exceeding these targets even occasionally is having dire consequences for portions of the Great Lakes.

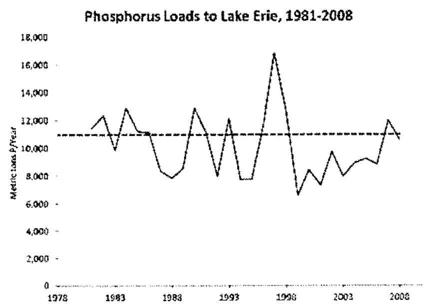


FIGURE 4
Estimated total phosphorus loads to Lake Erie from all sources (point and nonpoint), 1981-2008. Dashed line represents the Great Lakes Water Quality Agreement target load of 11,000 metric tons annually. (Graph courtesy D. Dolan, Univ. of Milwaukee-Green Bay, unpublished data.)

The original GLWQA of 1972 focused on point source phosphorus loads, and much of its success can be attributed to subsequent federal regulation of dischargers such as wastewater treatment plants. Subsequent revisions to the Agreement increased emphasis on nonpoint source pollution. Recently, however, the scientific community has raised concerns that point source pollution is still a serious problem in the Great Lakes. Recent research confirms other work indicating that point source phosphorus loads, particularly from municipal wastewater treatment plants via the Detroit River, are an important contributor to overall loading to western Lake Erie.[144] Continuing elevated loadings are likely due in part to the fact that cash-strapped municipalities across the region are struggling to maintain crumbling wastewater infrastructure, with federal funding inadequate to fulfill all needs. Outdated sewer systems that combine stormwater and sanitary wastewater are often overwhelmed by large rain events, resulting in combined sewer overflows (CSOs) that dump tens of billions of gallons of untreated sewage into the lakes each year.[145] Besides contributing phosphorus pollution to the Great Lakes, CSO events pose serious human health risks and can lead to beach closures.

Despite the importance of point sources, nonpoint sources such as runoff from agricultural fields are the primary contributor to Great Lakes total phosphorus loads. While acknowledging that other sources con-

BOX 5: IMPORTANCE OF NITROGEN AND OTHER NUTRIENTS TO ALGAL GROWTH

Phosphorus typically limits primary production in freshwater lakes,[177] but the importance of nitrogen should not be ignored, as it too can encourage algal growth under certain conditions. Recent research shows that phytoplankton in Lake Erie can be seasonally co-limited by nitrogen,[178] which can encourage blooms of nitrogen-fixing toxic blue-green algae such as *Anabaena*.[179] Nitrogen can be an important contributor to phytoplankton biomass in Lake Erie, particularly when phosphorus concentrations are high.[180]

The potential contribution of nitrogen to recent algal blooms is not necessarily due to changes in loading, but is primarily attributed to the alteration of in-lake nutrient dynamics by dreissenid mussels.[181] Experiments have shown that dreissenid mussels cause shifts in nitrogen-to-phosphorus ratios, favoring algae that are well-suited to N-limited conditions.[182] Once again, as with phosphorus and its relationship to algal growth, dreissenid mussels serve to decouple landscape nutrient inputs and primary production in the lakes. In addition to nitrogen, other nutrients such as iron and silica can contribute significantly to the growth of algae in the Great Lakes.[183]

tribute to nutrient pollution, scientists recognize that a majority of phosphorus loading to areas like Saginaw Bay and western Lake Erie come from agricultural nonpoint runoff,[146] and some experts recommend focusing efforts and resources on reducing loads from these sources to maximize water quality improvement.[147] The lack of systematic declines in total phosphorus loading in some areas of the Great Lakes—and potential recent increases—discussed above are largely due to inadequate agricultural practices to control phosphorus pollution in runoff.

In addition to total phosphorus loads exceeding targets in some areas, another troubling statistic suggests that the fraction of phosphorus entering the Great Lakes as dissolved or soluble reactive phosphorus (that is, biologically available phosphorus more easily taken up by algae) is increasing. In recent years, concentrations of soluble reactive phosphorus (SRP, also called dissolved reactive phosphorus) in nearshore Lake Ontario and the western basin of Lake Erie have increased.[148] Increases in SRP concentrations may be due in part to dreissenid mussels, which can uptake phosphorus in biologically unavailable forms and release it to the water column as SRP.[149] Increases in loading of SRP from streams and rivers may also be responsible for increased concentrations in the lakes. Current loads of SRP in the Maumee and Sandusky Rivers, two tributaries to western Lake Erie, are the highest they have been in 35 years (see Plot 1, pg. 18).[150] Exact causes of increased SRP loads in tributaries are uncertain, but experts believe they primarily result from farming practices in agriculture-heavy watersheds and from climate-related factors.[151]

In response to increased phosphorus loads and increases in the fraction of SRP, current phosphorus concentrations in some areas of the Great Lakes are not consistently meeting GLWQA targets (see, for example, Figure 2). Total phosphorus concentrations in Lake Erie, especially in the spring, began increasing as early as 1995.[152] Environment Canada and the U.S. EPA report that recently, concentrations in that lake are highly variable and frequently exceed targets, particularly in the western basin.[153] With respect to phosphorus concentrations, the two agencies rate the current condition of Lake Erie as "poor" with a trend of increasing phosphorus levels. [154] Environment Canada and the U.S. EPA also report that phosphorus concentrations in nearshore areas of lakes Michigan, Huron, and Ontario are high enough to support nuisance algae growth, even though phosphorus levels in offshore areas are at or well below targets.[155]

Impacts of excessive nutrients

Elevated concentrations of phosphorus in nearshore areas of lakes Michigan, Huron, Erie, and Ontario are high enough to encourage harmful blooms of algae such as *Cladophora* and *Microcystis*;[156] indeed, symptoms of eutrophication including harmful algal blooms and hypoxic zones have returned to parts of all the Great Lakes except Superior.[157] Water quality parameters and phytoplankton and zooplankton communities indicated a return to eutrophic conditions in Lake Erie, particularly in the western basin, beginning in the mid-1990s.[158] Blooms of blue-green algae re-appeared in Lake Erie in the mid-1990s and have since become an annual occurrence, with extensive blooms of *Microcystis* observed in 2007, 2008, and 2009.[159] As of late August, the summer

BOX 6: ECONOMIC IMPACTS OF GREAT LAKES EUTROPHICATION

The return of harmful algal blooms and hypoxia to the Great Lakes poses economic risks. The presence of smelly, unsightly, and potentially toxic algal blooms keeps people away from beaches and other recreational activities, resulting in lost tourism dollars. Across the U.S., blooms of harmful alga cause more than $80 million in economic damage annually.[184] *Cladophora* mats that wash ashore house *E. coli* bacteria whose concentrations are used as indicators of fecal contamination, meaning algal blooms potentially contribute to poor water quality and can trigger beach closures. Recent research suggests, however, that measuring *E. coli* at beaches plagued by *Cladophora* does not provide an accurate assessment of risks to human health.[185] Thus, it is possible that the presence of *Cladophora* has led to unnecessary beach closures – and beach closures are very costly in the Great Lakes, where coastal recreation provides the foundation for a vital tourism industry. For example, closing a Lake Michigan beach for a single day is estimated to result in economic losses of up to $37,000.[186] At the same time, current information does indicate continuing concerns about beach health: In 2006-07, only 47% of the Lake Erie beaches on the U.S. side were open for more than 95% of the beach season, and the EPA and Environment Canada report that beach water quality conditions on the lake are deteriorating.[187]

The potential impacts of eutrophication on Great Lakes fish communities are equally troubling. Recurring hypoxic zones in Lake Erie threaten the habitats and food resources that support economically important sport fish such as walleye and yellow perch.[188] Lake Erie, the most biologically productive of the Great Lakes, forms the basis of a regional recreational fishery whose estimated worth exceeds $7 billion annually in the U.S.[189] Clearly, symptoms of nutrient pollution such as harmful algal blooms and hypoxia in the Great Lakes have serious economic implications, and these problems will only worsen as eutrophication accelerates.

2011 *Microcystis* bloom in western Lake Erie was 2.5 times denser than the previous record bloom of 2009 (see pg. 18).[160] While not all types of *Microcystis* produce toxins, research shows that toxin-producing strains of these blue-green algae are present in lakes Erie and Ontario and are capable of producing toxin concentrations high enough to be harmful to human health.[161] Levels of *Microcystis* toxins in early stages of the summer 2011 western Lake Erie bloom reached more than 1000 times World Health Organization guidelines for drinking water safety. [162] Recent research indicates that toxic blue-green algal blooms in tributaries to western Lake Erie are starting earlier in the year and farther upstream than was previously the case.[163] Washed-up mats of *Cladophora* are once again a common sight along shorelines of lakes Erie and Ontario, and in some areas of lakes Michigan and Huron.[164] In addition to the resurgence of harmful blooms of *Cladophora* and *Microcystis*, new bloom-forming algae are beginning to appear in the Great Lakes. *Lyngbya wollei*, a potentially toxic, mat-forming blue-green alga from the southeastern U.S., was discovered washing onshore in western Lake Erie beginning in 2006. *Lyngbya* has different light and habitat requirements than similar mat-forming algae like *Cladophora*, so it may be able to colonize areas the latter has not.[165]

Coincident with the return of large algal blooms, the size and duration of hypoxic areas in the bottom waters of Lake Erie are increasing.[166] In 2005, a hypoxic zone with an area of about 10,000 square kilometers developed in central Lake Erie—one of the largest "dead zones" ever recorded in the lake.[167] In addition to negatively impacting fish and other organisms, hypoxia can re-release phosphorus formerly bound up in sediments. Thus, Lake Erie's hypoxic zones may alter phosphorus cycling to further encourage algal blooms[168]—creating a harmful feedback loop.

Great Lakes food webs are already being impacted by the reappearance of eutrophic conditions. Hatches of Lake Erie walleye and perch were below average in 5 out of 6 years from 2004 to 2009.[169] Hypoxia in Lake Erie's central basin has reduced habitat quality for many species of fish and has the potential to impact fish community structure and population dynamics.[170] Cyanobacterial toxins such as those produced by *Microcystis* can be harmful to invertebrates and fishes and can accumulate up food webs, significantly impacting their structure and function.[171] Mats of *Cladophora* harbor bacteria responsible for recent outbreaks of avian botulism that have killed thousands of birds along the Great Lakes.[172]

The resurgence of eutrophication in nearshore areas of the Great Lakes also has serious implications for human health. As previously discussed, chemicals produced by some blue-green algae can be toxic to humans, causing respiratory and gastrointestinal symptoms, damaging liver tissue, and promoting tumors.[173] In 2010, nine people were sickened by toxic blue-green algae in an inland lake in Ohio, and three pets died after coming in contact with the water.[174] Blue-green algal toxins can even lead to death in humans; in an infamous example, 55 people in Brazil were killed by toxic *Microcystis* that had contaminated dialysis units.[175] *Cladophora* blooms harbor and encourage the growth of harmful bacteria such as *E.coli* and *Salmonella* that can be released to surrounding waters, sickening humans who come in contact with contaminated water or beaches. [176]

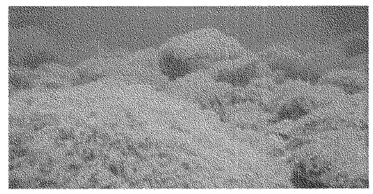
It is clear from the return of eutrophic conditions in nearshore areas of the Great Lakes that algae are booming, feasting on nutrients from the land and encouraged by invasive species. These algal blooms and other manifestations of eutrophication can cause a number of economic impacts (see Box 6). These "feast" conditions are even more striking when compared to the "famine" that is devastating offshore food webs (see Section 3 and pgs. 18-19).

Algae in Maumee Bay (Photo: S. Bihn, Lake Erie Waterkeeper)

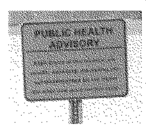
FEAST

High levels of phosphorus in nearshore areas of the Great Lakes, particularly in western Lake Erie, are causing toxic and nuisance algal blooms and creating oxygen-poor "dead zones" in deep areas. While both nutrient loads and concentrations have declined over the past few decades, concentrations (in particular in nearshore areas such as western Lake Erie) often remain above target levels. Excessive nutrient loads come from nonpoint sources such as fertilizer-rich runoff from agricultural fields and from point sources such as sewage treatment plants. Invasive zebra and quagga mussels exacerbate this problem by shunting phosphorus already within the lakes towards shore and trapping phosphorus coming from the land. In addition, the proportion of phosphorus loads entering western Lake Erie from tributaries that consists of dissolved phosphorus is increasing—meaning more phosphorus is readily available to algae (see Plot 1). The combination of available phosphorus and other factors (including adequate light and warm water temperatures) can lead to large harmful algal blooms, as was the case in the August-September 2011 western Lake Erie bloom, in which high concentrations were observed throughout most of the basin (see image at bottom left).

In the summer of 2011, western Lake Erie experienced the most severe bloom of toxic algae ever recorded. The species of blue-green algae primarily responsible for the bloom, *Microcystis*, produces a chemical that is toxic to humans and wildlife and can cause sickness and even death. Levels of toxins measured in the 2011 bloom were more than 1000 times the World Health Organization guidelines for drinking water. Advisories were posted on beaches along the western basin of Lake Erie, warning swimmers against contacting the water.



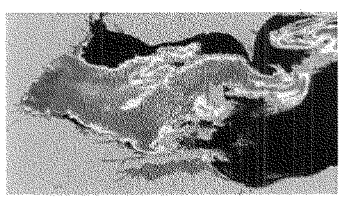
Nuisance algae Cladophora *blanketing bottom surface in western Lake Michigan. (Photo: H. Bootsma, University of Wisconsin-Milwaukee)*

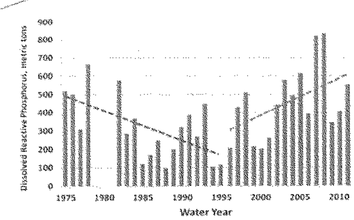


A toxic Microcystis *bloom washes up on the shore of Maumee Bay in western Lake Erie on August 29, 2011. (Photo: S. Bihn, Western Lake Erie Waterkeeper)*

A public health advisory at a Maumee Bay, Lake Erie beach warns swimmers against contacting water contaminated with a toxic bloom of Microcystis. *(Photo: S. Bihn, Western Lake Erie Waterkeeper)*

MERIS satellite image from European Space Agency showing massive Microcystis *bloom in western Lake Erie on September 3, 2011. Red indicates highest concentrations of toxic algae. (Image from NOAA Great Lakes Environmental Research Laboratory Experimental Lake Erie Harmful Algal Bloom Bulletin, 8 September 2011, available from: http://www.glerl.noaa.gov/res/Centers/HABS/lake_erie_hab/archive/bulletin_2011-014.pdf.)*

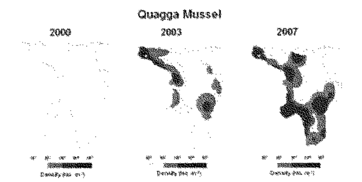




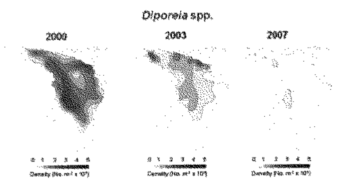
PLOT 1. Annual export of dissolved reactive phosphorus in metric tons from the **Maumee River at Waterville, OH**, as measured by the National Center for Water Quality Research at Heidelberg University. (Courtesy of D. Baker, Heidelberg University, unpublished data).

FAMINE

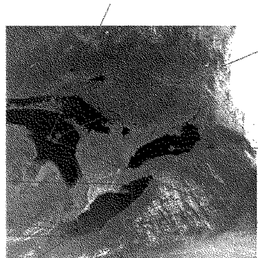
In contrast to the nearshore region, offshore areas of the Great Lakes have too few nutrients that are unable to support healthy biological communities. Invasive quagga mussels have expanded rapidly offshore and number in the trillions (see Plot 2). These tiny organisms are capable of filtering huge amounts of water, removing nutrients and algae from the water column, and pushing phosphorus to nearshore areas. Although excessive amounts of nutrients and algae in the nearshore are causing serious problems, their relative absence in the offshore is causing different but equally serious ecosystem changes. One dramatic change has been the drastic declines in the bottom-dwelling organism *Diporeia*, which has essentially disappeared in most areas of the lower lakes (see Plot 3). Significant changes have also occurred in the offshore, open waters—for example, springtime primary production in Lake Michigan has declined by over 80% since the mid-1980s (see Plot 4). Due to the crash in the lower levels of the food web of Lake Huron, prey fish populations have declined as well, with 95% of the deepwater prey fish biomass lost in less than two decades (see Plot 5). The loss of prey fish populations has contributed to a crash in Chinook salmon in Lake Huron, a recreationally and economically important fishery.



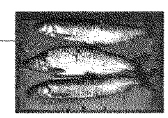
PLOT 2. Expansion of invasive quagga mussels (densities in numbers of individuals per square meter) in the waters of **Lake Huron** between 2000 and 2007. (Courtesy T. Nalepa, NOAA, Great Lakes Environmental Research Laboratory.)

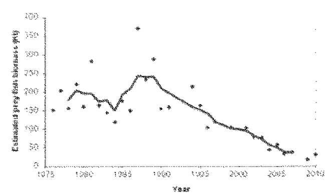


PLOT 3. Disappearance of the bottom-dwelling shrimp-like organism *Diporeia* in the waters of **Lake Huron** between 2000 and 2007. Note densities are in numbers of individuals per square meter, divided by 1,000; hence, the zone in the western portion of the lake in 2000 with the highest abundance was over 3,000 individuals/m2. (Courtesy T. Nalepa, NOAA, Great Lakes Environmental Research Laboratory.)

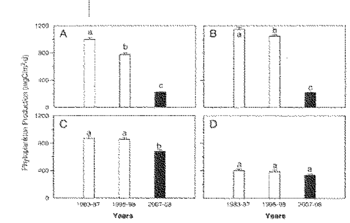


Emaciated (top, bottom) lake whitefish from Lake Ontario. (Photo: J. Hoyle, Ontario Ministry of Natural Resources)





PLOT 5. Estimated total lakewide biomass of offshore demersal (deepwater) prey fishes (kilotons) in **Lake Huron**. The solid line is the 5-year moving average of biomass, and the dashed line represents the average biomass from 1976-1994. Offshore demersal prey fishes include bloater, rainbow smelt, alewife, ninespine stickleback, trout perch, sculpins (deepwater and slimy), and round goby. Data are from the U.S. Geological Survey long-term fall bottom trawl survey. (Courtesy S.C. Riley, USGS Great Lakes Science Center, unpublished data.)



PLOT 4. Estimates of daily, areal integrated primary production in **Lake Michigan**, by thermal periods of the year, over three decades. A, spring isothermal mixing; B. May isothermal mixing; C midstratification, (D) late stratification. Means with different letters (a,b,c) indicating significant differences. Note significant declines for last decade, for each thermal period except late stratification. (Reprinted from Journal of Great Lakes Research, V. 36, Supplement 3, Fahnenstiel, G., Pothoven, S., Vanderploeg H., Klarer, D., Nalepa, T., and Scavia, D. Recent changes in primary production and phytoplankton in the offshore region of southeastern Lake Michigan, pp. 20-29, 2010, with permission from Elsevier.)

SECTION 5

EXISTING NUTRIENT REDUCTION PROGRAMS AND POLICIES

The Great Lakes are among the most intensely managed bodies of water in the world. There are hundreds of laws, programs, action plans and task forces from the local to the international level to protect Great Lakes resources. To provide an overview of efforts to reduce nutrient pollution and address ecosystem changes in the Great Lakes, this section highlights several significant laws and programs pertaining to phosphorus reductions.

Binational, federal, and state nutrient reduction strategies

The first international effort to protect the Great Lakes was the **1909 Boundary Waters Treaty.** The treaty obliged the U.S. and Canada to protect international waters from pollution, but provided no monitoring or enforcement mechanism to ensure that the Parties abided by their commitments. The Treaty formed the **International Joint Commission (IJC)**, a binational advisory board, to counsel both nations on the administration of their shared bodies of water. In response to widespread eutrophication and phosphorus loading in the Great Lakes during the 1960s that lead to fish die-offs, toxic algal blooms and the biological "death" of Lake Erie (see Section 2), the IJC recommended in 1970 that both nations enter into a phosphorus control agreement.

The early 1970s saw both extensive environmental activism and the fruition of numerous environmental advances in North America. The **Great Lakes Water Quality Agreement (GLWQA)** was signed in 1972 by the U.S. and Canada, ushering in an array of state and federal programs to address water quality issues in the Great Lakes Basin. Concomitant with this binational development, and to provide the legislative muscle to implement water quality controls across the U.S., Congress passed the **Clean Water Act** earlier that year. Both governments had recognized the need for federal agencies to monitor and enforce environmental laws, leading to the creation of the **U.S. Environmental Protection Agency (EPA)** in 1970 and **Environment Canada** in 1971.

The GLWQA was a watershed agreement in the area of nutrient reduction, particularly from point sources. Following implementation of programs in both countries, annual phosphorus loadings decreased due to several pollution reduction measures, some mandated by law and some implemented voluntarily. Important measures for reducing point sources of pollution included the promotion of phosphorus-free detergents, limits on phosphorus concentrations in wastewater effluent, and improvements made to sewage treatment plants and sewer systems. These controls on point sources were vital, but a 1978 report to the IJC from the **International Reference Group on Great Lakes Pollution from Land Use Activities (PLUARG)** recognized the importance of nonpoint nutrient loadings and proposed solutions. Revisions to the GLWQA in 1978 included recommended measures to reduce nonpoint pollution, which included changes in agricultural practices such as conservation tillage, animal husbandry control measures, and other practices.

Under the Clean Water Act, states must set ambient water quality standards to define acceptable pollutant levels in water bodies, as well as conduct monitoring and assessment to gauge whether standards are being met. States must identify waters not meeting water quality standards as "impaired" and are required to develop **total maximum daily loads (TMDLs)** for the pollutant(s) of concern (including nutrients such as phosphorus and nitrogen).[90] However, a number of states have lagged in developing and implementing TMDLs, including for nutrients. Perhaps the single most effective requirement of the Clean Water Act in the reduction of phosphorus is the **National Pollutant Discharge Elimination System (NPDES)** program, requiring permits for the release of wastewater from point sources. Permit limits for nutrients have been increasingly included in discharge permits over the past two decades.

Another important Clean Water Act provision that addresses nutrients is the Section 319 provision addressing nonpoint source (NPS) pollution , added to the CWA in 1987. Section 319(h) established a grant program whereby EPA is authorized to award states funds to implement programs to reduce nonpoint source pollution (including nutrient pollution), if they have approved Nonpoint Source Assessment Reports and Nonpoint Source Management Programs. The program has included both base funds (for base NPS program operations) and incremental funds (designated for watershed-based plans and TMDLs); from 1999-2005, over $150 million annually was awarded to states through the program.[191]

The **U.S. Farm Bill** includes a number of conservation incentive programs for farmers, including programs to reduce phosphorus-rich agricultural inputs, control runoff, protect wetlands and groundwater, and prevent erosion that contributes to nutrient loading into public waters. Programs include the Environmental Quality Incentives Program, the Wildlife Habitat Incentives Program, Agricultural Management Assistance, the Conservation Reserve Program, the Conservation Stewardship Program, the Conservation Reserve Enhancement Program, the Wetlands Reserve Program and the Great Lakes Basin Program for Soil Erosion and Sediment Control. Participation in these voluntary programs helps agricultural operations reduce pollution (potentially including soluble reactive phosphorus) which otherwise contributes to violations of water quality standards while also improving the efficiency of operations.[192]

Binational and federal efforts to control phosphorus were largely successful in reversing eutrophication in the Great Lakes in the 1970s and 1980s, as documented in Section 2. Despite these earlier successes, signs of cultural eutrophication have returned to the Great Lakes in recent years. As discussed in Section 4, ecosystem changes driven by invasive species and increases in the amount of dissolved phosphorus in agricultural runoff have led to a return in harmful algal blooms and dead zones. Clearly, efforts by the U.S. and Canada to reduce nutrient pollution are no longer sufficient.

In recognition of the need for more aggressive efforts to address impairments in the Great Lakes, and following on the production of the Great Lakes Regional Collaboration Strategy report in 2005, the **Great Lakes Restoration Initiative** (GLRI) was proposed by President Obama in 2009, with $475 million appropriated the first year, and $300 million the second year. The five-year GLRI effort is dedicated to five major focus areas, including Nearshore Health and Nonpoint Source Pollution and Invasive Species.[193] Concurrent with initial funding of the program, the EPA developed the GLRI Action Plan, which identifies broad goals, measurable ecological targets and specific actions for each of the five focus areas. Strategic actions related to nutrients will identify sources and reduce loadings of nutrients and soil erosion, and research and modelling will identify effective actions to prevent and reduce the number and severity of incidences of ecosystem disruptions such as harmful algal blooms and other issues associated with eutrophication. Sustainable watershed management practices will be developed and applied to reduce export of nutrients and soils to the nearshore waters. In addition, the Action Plan includes a goal of establishing and implementing TMDLs for phosphorus.[194]

Finally, there are a number of programs at the state, provincial, and municipal levels addressing nutrients, including programs distinct from other federal programs or mandatory requirements. One example is the Ohio Lake Erie Phosphorus Task Force (see Box 7).

BOX 7: FEATURED STATE PROGRAM

In 2007, the Ohio Environmental Protection Agency created the multi-stakeholder **Ohio Lake Erie Phosphorus Task Force** and charged it with studying the issue of increasing soluble reactive phosphorus (SRP) loads to Lake Erie. Specific tasks included identifying potential sources, determining the importance of each source, and recommending policy and management solutions to decrease SRP loads to Lake Erie. In its 2010 final report,[195] the Task Force concluded that runoff from applications of nutrients to agricultural fields was the primary cause of increased SRP loads to Lake Erie and recommended specific actions for farmers to take. The report also investigated the contribution of other pollution sources, such as lawn fertilizers and point sources, and provided suggestions for reducing SRP loads from these sectors. Additionally, Task Force members made recommendations on improvements to monitoring activities and identified research needs to further understanding of SRP loading.

SECTION 6

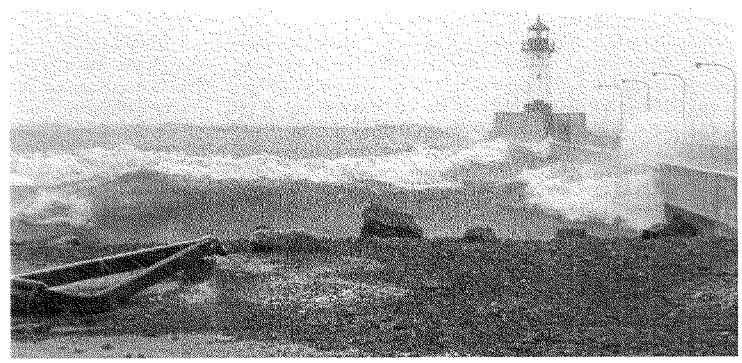
LOOKING TO THE FUTURE

Nutrient loadings and dynamics in the Great Lakes ecosystem have been altered by humans since the first days of European settlement in the basin. In the future, new stressors are anticipated to impact the Great Lakes, and current problems such as invasive species will continue to worsen in the absence of additional action. Scientists have identified several of these future stressors that could influence Great Lakes nutrient dynamics.

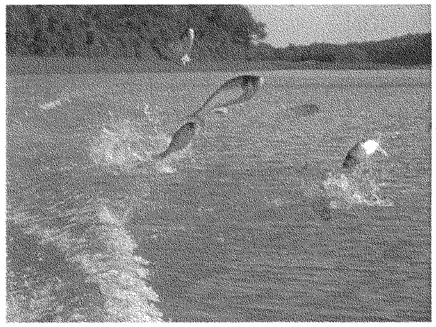
Perhaps the most serious threat to the future of the Great Lakes is global climate change. It is predicted that by the end of the century, air temperatures in the Great Lakes region could warm by up to 12°F in winter and 20°F in summer. [196] In fact, climate change is already occurring in the Great Lakes. Annual average temperatures have increased by 2 to 4°F and extreme heat and heavy precipitation events are increasing in frequency by up to 100%. Winters and the duration of lake ice cover are getting shorter, with spring ice breakup occurring earlier by 2 days per decade.[197] These changes will only become more extreme as climate change progresses. Average surface water temperatures will likely increase; in 2010, several of the Great Lakes reached the warmest surface water temperatures on record.[198] As of August 2011, summer temperatures in most of the lakes were well above recent (1992-2010) averages.[199] Due to increased air and water temperatures and shorter periods of ice cover, lake levels are expected to decline,[200] though some models indicate more ambiguous trends in water levels.[201] Great Lakes water levels naturally fluctuate, but levels over the past decade in lakes Michigan, Huron, and Superior have been low compared to historic averages.[202]

These climatic changes have serious implications for nutrients and eutrophication. Warming water temperatures will alter the thermal structure of the lakes, which in turn influences nutrient cycling and the development of hypoxic zones.[203] Changes in thermal structure leading to decreased mixing could cause larger and more frequent hypoxia in some parts of the Great Lakes.[204] Warmer water temperatures can further stimulate algal blooms, through, for example, increased activity of microorganisms releasing phosphorus from organic matter.[205] More frequent and severe precipitation events in the future will cause increased loads of phosphorus to wash from the landscape into the lakes. High phosphorus loads to Lake Erie in 1997 and 1998 were blamed on increased tributary loads resulting from large, anomalous storms.[206] More frequent and intense large storms

Storm surge at Canal Park, Duluth, MN (Photo: Minnesota Sea Grant)



will also increase nutrient pollution from combined sewer overflows.[207] Clearly, climate change has the potential to exacerbate eutrophic conditions in the Great Lakes through several mechanisms.



Invasive silver carp on Illinois River (Photo: T. Lawrence, Great Lakes Fishery Commission)

Other future stressors on the Great Lakes that will influence nutrients include human population growth and land use change. The population of the Great Lakes region continues to grow, and the density of people living in urban areas (metropolitan census areas, including suburbs) is increasing.[208] As more people move to cities, and as land is developed at a faster rate than population growth (i.e., as sprawl increases), the percentage of impervious surfaces in the Great Lakes watershed will also increase, causing more nonpoint pollution. According to the U.S. EPA, all of the Great Lakes except Lake Superior are in degraded condition with respect to the proportion of impervious surface in their watersheds; Lake Erie in particular is at risk with more than 15% of its U.S. watershed impervious.[209] Larger populations will also place more stress on already inadequate wastewater infrastructure. As the Great Lakes population grows, land cover patterns are also changing. The extent and composition of coastal wetlands across the Great Lakes are classified generally as "deteriorating" by Environment Canada and U.S. EPA.[210] Natural areas such as forests are being converted to developed land. From 1992 to 2001, there was a 33.5 % increase in the area of low-intensity development in the U.S. Great Lakes states.[211] During this period, Lake Erie's watershed experienced the largest proportion of land converted to development. Destroying forests and wetlands—which provide buffers that keep nutrients and other pollutants out of waterways—and replacing them with development will add more stress to areas of the Great Lakes already facing eutrophication.

Agriculture is perhaps the most important land use category influencing nutrients and eutrophication. In areas with significant agricultural development, a majority of phosphorus loads result from runoff from farm fields. Thus, future changes in agricultural land use practices will be important in determining future loading scenarios. Although agricultural lands are actually being lost to development in the Great Lakes watershed,[212] changes in the way land is farmed may be more important in determining future nutrient loads. Current policies encouraging the development of biofuels (e.g., promotion of ethanol made from corn) are driving agricultural land use practices that could result in added pressure on Great Lakes water quality. Research being coordinated by the U.S. EPA is examining how future land use scenarios will impact ecosystem services; part of this work will predict how trophic states of the Great Lakes will respond to potential future nutrient loading scenarios.[213]

It is clear that invasive species can alter nutrient dynamics in the Great Lakes, as evidenced by the role of dreissenid mussels in nearshore eutrophication and offshore oligotrophication. The basin is also faced with the threat of numerous future invaders[214] that have the potential to significantly affect the ecosystem. Of particular concern are two species of Asian carp that are taking over the Mississippi River watershed and are at risk of entering the Great Lakes via several pathways, including the Chicago Area Waterway System. Asian carp are filter-feeding fish that feast voraciously on phytoplankton and zooplankton, and if they successfully invade the Great Lakes they have the potential to further deplete the already-stressed lower food web and outcompete native fishes.[215] Research suggests that the western basin of Lake Erie would provide particularly suitable habitat for Asian carp, in part because of its greater productivity.[216] As eutrophication progresses, food resources for hungry Asian carp will increase. In addition, a recent study found that Asian carp can consume *Cladophora*.[217] Ongoing expansion of blooms of harmful algae like *Cladophora* would mean conditions for Asian carp could improve at the same time they are degraded for native fishes. Obviously, eutrophication has the potential to facilitate the invasion of non-native species into the Great Lakes—and only time will tell how new invaders might in turn further influence nutrient cycling.

SECTION 7

RECOMMENDATIONS

Current nutrient and invasive species management policies and programs are insufficient to protect the Great Lakes. Hypoxia persists in central Lake Erie and eutrophication and algal blooms continue to plague western Lake Erie and other nearshore areas of the lakes while many offshore waters (in particular in Lake Huron) have very low nutrient levels and declining fish production. Immediate action must be taken to prevent further deterioration of these ecosystems on which fish, wildlife and humans depend. This complex problem will require creative and integrated solutions in policy, research and monitoring, and public education.

Policy and Management

Existing policies and management programs fall short in recognizing that invasive species such as zebra and quagga mussels have changed the fundamental structure of the lakes. Three overarching recommendations are the following:

1. **While emphasizing a broad lake- or ecosystem-wide management approach to nutrient problems, management and policy need to be refined at smaller scales (e.g., sub-basin or watershed) as appropriate, to take into account different extents of problems in different areas.**
2. **Recognizing that although implementation of policies specific to nutrients and invasive species (in particular invasive mussels) is critical, we need to explore policies that can address both stresses in an integrated way.**
3. **Further reductions in nutrient loading are necessary, in particular in priority watersheds and from agricultural sources, where targeted programs should be pursued to address specific nutrient impairment problems.**

There are many agreements, policies and programs that do or can address nutrient problems in the Great Lakes, and it is essential that such efforts be updated as necessary to keep pace with changing ecosystems. Some potential changes in agreements, policies, and programs include the following:

- The Great Lakes Water Quality Agreement (GLWQA), the primary framework for coordinated phosphorus reduction efforts between the U.S. and Canada, must recognize that **the Great Lakes are not a single ecosystem,** nor can each lake be treated as a single unit. Different areas of the lakes will respond to nutrient inputs in different ways; thus, water quality standards and GLWQA phosphorus loading targets should be developed for individual regions of the lakes (including nearshore vs. offshore). Phosphorus loading targets for western Lake Erie may well be different from targets for the eastern basin. Given that zebra and quagga mussels are redirecting phosphorus away from the offshore and negatively impacting offshore food webs, innovative policy tools and solutions will need to be applied to regain balance in the lakes.
- The current renegotiation of the GLWQA is an excellent opportunity to encourage policies that build on the scientific advances (including understanding food web changes and ecosystem modeling) that have occured since the last update to the Agreement. **Updated phosphorus targets must be calculated using the best available scientific information** on the state of the Great Lakes. Target levels of phosphorus and chlorophyll representing improved water quality and reduced algae production should be established for distinct lake regions, and scientific models should be used to calculate load reductions required to meet in-lake targets. Additionally, targets for community composition of phytoplankton (which are tied to water quality parameters) should be established.
- It is important to continue monitoring and regulating total phosphorus loads, because target loading levels are not being met consistently across the Great Lakes basin. However, **the significant contribution of soluble reactive phosphorus (SRP) in western Lake Erie in particular and the fact that SRP loads are increasing must be recognized.** Agricultural practices targeted to reducing SRP should be encouraged in addition to those that reduce overall phosphorus loading. See report of the Ohio Lake Erie Phosphorus Task Force for more specific recommendations.[218]
- To increase the effectiveness of the GLWQA, **changes should be made to its structure and implementation.** The Agreement should include enforcement mechanisms to ensure targets are met, with agreed-upon time

tables for meeting water quality objectives. In addition, given the new paradigm of rapid ecosystem change brought about by invasive species, the GLWQA review process might need to be adjusted so that water quality targets are reevaluated on shorter time scales.

- The renegotiated GLWQA should include creation of a Great Lakes-wide **Phosphorus Task Force**, similar to the Ohio Lake Erie Phosphorus Task Force (see Box 7, Section 5), to investigate the issues of eutrophication and changes in phosphorus loads and concentrations (and components of phosphorus, such as SRP) in the nearshore and offshore. The Task Force should provide the U.S. and Canadian governments and the International Joint Commission with detailed management and policy recommendations for meeting water quality goals across the basin. Such an entity should be well integrated with other relevant bodies (such as Lakewide Management Plans (LaMPs)), and have representatives from all relevant sectors, including federal, state, municipal, and tribal agencies, the International Joint Commission, academia, agriculture and industry, and nongovernmental organizations.

In addition to working binationally, we need to **maximize the ability of existing laws, regulations and programs** to control nutrient pollution at the municipal, state, and federal levels. Recommendations here are focused on the U.S. side, while it is recognized that strengthening of Canadian programs is also essential to fully address nutrient problems in the Great Lakes. Some key measures/changes needed on the U.S. side include the following:

- Programs to reduce nonpoint runoff from agricultural land, including under the **Farm Bill,** must be strengthened.
  - Assist farmers in pursuing financial assistance through Farm Bill Programs, including the Environmental Quality Incentives Program, the Conservation Reserve Program, the Conservation Stewardship Program, and other programs on targeted priority watersheds, as well as other federal funding sources, to reduce nutrient and sediment runoff from agricultural lands.
  - Nutrient management programs should use a watershed-based approach to tailor efforts to specific areas.[219] Funding should be targeted to priority areas contributing large amounts of phosphorus loading as identified by research.
  - Provide more oversight of agricultural operations participating in Farm Bill programs, and recommend wider buffer zones between all row crops and surface waters.
  - Re-invent the Great Lakes Basin Program for Soil Erosion and Sediment Control—currently authorized in the Farm Bill—into a solution-based restoration implementation program. This program has had much success and should be re-designed to improve water quality in targeted areas around the Great Lakes by controlling sediment and reducing nutrient runoff that causes harmful algae blooms.
  - For Lake Erie in particular, prioritize and implement key recommendations of the Ohio Lake Erie Phosphorus Task Force, including to increase training/outreach on appropriate rates and timing of agronomic application of fertilizers; strengthen and expand use of phosphorus soil test programs; develop or strengthen nutrient management tools (including phosphorus runoff risk screening and assessment tools); and optimize and expand implementation of best management practices, including adoption by cost-share agencies of innovative approaches (e.g. fund allocation based on screening tool).
- Although efforts should be centered on reducing nonpoint phosphorus loading, point source pollution should be further addressed through aggressive implementation of **Clean Water Act** programs. This will include increased activities through:
  - Establishment of protective nutrient water quality criteria by each of the Great Lakes states (including potentially revising existing criteria).
  - Effective development and implementation of total maximum daily loads, with U.S. Environmental Protection Agency (EPA) playing a key role in coordinating individual Great Lake or basin total maximum daily loads for nutrients.
  - Tighter National Pollutant Discharge Elimination System permit limits, where necessary, for wastewater treatment plants.
  - Consideration of additional limits for nutrients in municipal stormwater permits.

The Clean Water Act should also be used as a vehicle to encourage the reduction of nonpoint source pollution through fully funded and implemented Section 319 programs, including emphasizing watersheds with significant nutrient problems.

On the Canadian side, policy advances are needed at the local, provincial, and federal levels. Though the regulatory and voluntary frameworks differ from the U.S. side, similar types of actions are needed, including the following:[220]

- Address loadings from point sources, including upgrading municipal wastewater treatment plants and reducing levels of phosphorus in detergents.
- Promote expansion or maintenance of natural cover, to reduce flows and sediment, and nutrient export from watersheds;
- Expand the scope and intensity of best management practices in agricultural lands, including through improved tillage practices, improved manure management, and adopting new technologies for erosion control.
- Ensure that all municipalities have a Pollution Prevention Control Plan, with components that may include the retrofit/design of stormwater facilities and adoption of sustainable planning to reduce flows, sediment and nutrient loads to surface waters.

Also, **improved coordination among programs** at all levels of government is needed. Linkages between the GLWQA and Farm Bill programs, for example, should be explored and encouraged. Managers should pursue harmonization of ecosystem goals as appropriate (e.g., GLWQA water quality targets, LaMP objectives,[221] fish community objectives as set by the Great Lakes Fishery Commission[222], and state water quality criteria). Fishery management is a valuable tool for dealing with ecosystem changes, and while managers must adjust to new ecosystem regimes with changes in stocking and other practices,[223] innovative solutions to the feast/famine dichotomy might be found by working with fisheries resource groups. For instance, managers could alter stocking practices to encourage top-level predators such as Atlantic salmon that are better adapted to new offshore food webs.[224]

Finally, it is critical that **adequate funding** be provided for all programs, including through the Great Lakes Restoration Initiative (GLRI) Focus Area 3: Nearshore Health and Nonpoint Source Pollution.[225] The current higher levels of federal funding for the Great Lakes on the U.S. side must be invested wisely in efforts to restore aquatic habitats as well as in projects that reduce runoff from targeted watersheds. Similar increased funding efforts are needed on the Canadian side as well.

Research and Monitoring

Research and monitoring programs must **evaluate, adjust to, and study new ecosystem regimes** to improve our understanding of nutrient dynamics in the Great Lakes. For instance, eutrophication models need to be improved to account for altered nutrient processes following the dreissenid invasions.[226] Current monitoring programs, such as the EPA's offshore surveillance program,[227] leave a gap in monitoring nearshore areas of the lakes that prevents better understanding of that important part of the ecosystem. Offshore monitoring efforts are important and should be sustained; however, given the new feast/famine dichotomy, **standardized, regular, and targeted monitoring is needed in nearshore areas.** Monitoring in the nearshore zone is particularly important because blooms of harmful algae such as *Microcystis* and *Cladophora* occur there, and human uses are concentrated along shorelines. Continued and enhanced tributary monitoring is also needed to understand how phosphorus is moving from the land into the lakes. Additionally, **monitoring efforts could be improved through coordination.** For example, EPA's offshore surveillance program performs more frequent, regular monitoring than Environment Canada, but Canada's program has greater spatial coverage in each lake. Working together, these two programs could increase the frequency and extent of monitoring. The Binational Coordinated Science and Monitoring Initiative[228] offers promise to help integrate and coordinate monitoring efforts, but needs adequate sustained funding and would benefit from ongoing input from stakeholders in each lake basin. Finally, monitoring of fish populations and other organisms must adjust to new ecosystem paradigms. Current fishery assessments and research are focused on the offshore. There is a need to develop new fisheries assessment programs that include both nearshore and offshore habitats. Similarly, increased monitoring of other aspects of the altered nearshore waters and habitats is necessary. [229]

In spite of new efforts such as the GLRI, scientists in the Great Lakes are faced with limited funding and resources to carry out research and monitoring programs. Thus, **scientific efforts must focus on priority topics and geographic areas as identified through expert deliberations.** For example, the Lake Erie Millenium Network's 2011 Synthesis Team Report[230] identifies specific research needs to better understand processes of nutrient transport from the landscape to the lakes. The role of nitrogen in encouraging blooms of toxic *Microcystis* is poorly understood and should be further studied.[231]

Finally, there is a need to **better integrate the results of research and monitoring into development and implementation of policy.** As science advances our understanding of new nutrient dynamics, invasive species changes and ecosystem impacts, this knowledge must help guide the development of water quality objectives and loading targets, as well as programs to meet the targets.

Education and Outreach

Changes to policies and research efforts are necessary to solve the nutrient problems in the Great Lakes, but on their own will not be sufficient. An educated and informed public of water quality stewards will be necessary to ensure that nutrient reduction efforts are successful. Thus, we must **enhance outreach and education to inform the public on the feast/famine problem,** its causes, and its solutions. It is vital that the public understands both nearshore eutrophication and offshore oligotrophication and how the two problems are linked. This can be partially accomplished through the promotion of existing outreach and education efforts, such as EPA's Nitrogen and Phosphorus Pollution Outreach Portal.[232] Outreach efforts must be ramped up across the basin to empower the public by providing simple actions they can take (see "What You Can Do" below). The public also should be made aware of opportunities to weigh in on policies and planning efforts such as watershed plans, and should be encouraged to actively participate in the governance of their precious water resources. Existing public engagement and outreach efforts through bodies and institutions such as LaMP Public Forums, Sea Grant outreach programs, and university extension programs must be fully supported.

Invasive Species

This report has focused on the dichotomy between feast and famine in the Great Lakes, where two invasive mussel species the size of a fingernail have changed the way an entire ecosystem functions and responds to human-induced stressors. Clearly, invasive species can impact the lakes in ways we cannot anticipate. Thus, we must make every effort to **prevent the introduction and spread of invasive species in the Great Lakes.** Example measures that should be taken include supporting strict regulation of organisms in trade, tightening controls on ballast water in commercial ships, and preventing the movement of organisms through canals and waterways (e.g., through building a permanent separation between the Mississippi River and Great Lakes Basins in the Chicago area). In addition, efforts to include a comprehensive invasive species annex in the GLWQA must be encouraged to reflect the important connections between non-native organisms and water quality.

At present, there is little that can be done to control or eradicate the invasive dreissenid mussels that are wreaking havoc on Great Lakes water quality and food webs. However, we must continue to **explore innovative control methods for zebra and quagga mussels** and other harmful invasive species. Important work is already underway and should continue to be supported. For example, scientists have developed, and a private company is now marketing, a product that kills only invasive dreissenid mussels. Currently, studies are examining the use of this control method in open waters such as the Great Lakes.[233] Researchers at the U.S. Geological Survey are studying the biology of invasive mussels to inform selective control methods.[234] Additionally, many fish species in the Great Lakes consume dreissenids,[235] potentially representing a powerful biological control method that could be encouraged.[236] These and other efforts to develop creative invasive species control solutions should be supported.

WHAT YOU CAN DO

Although residential areas contribute only a small amount to phosphorus pollution, every effort helps to prevent eutrophication in the Great Lakes. There are simple things the average citizen can do to reduce runoff of nutrients from their yards:[237]

- Use only phosphorus-free fertilizer that is designated for lawns;
- Apply fertilizer in smaller quantities and less often, and not before anticipated heavy rainfall;
- Do not apply fertilizer within 25 feet of any body of water;
- Get your soil tested to see what nutrients your lawn needs;
- Pick up all pet waste and dispose in a garbage can;
- Maintain your septic system properly;
- Keep water on your property by installing rain gardens and/or rain barrels.

There are also actions you can take to prevent the introduction and transfer of invasive species that might otherwise harm the Great Lakes. If you boat or fish in the Great Lakes or any inland waters in the basin, follow recommended guidelines to prevent the spread of invasive species. Visit http://www.protectyourwaters.net/ for more information. Aquarium enthusiasts and water gardeners should be aware of invasive species and avoid releasing them into the environment. See http://www.habitattitude.net/ for recommended guidelines.

ENDNOTES

1 Government of Canada and U.S. Environmental Protection Agency, 1995. *The Great Lakes: An Environmental Atlas and Resource Book*. Fuller, K., Shear, H., and Wittig, J. (Eds.) Available from: http://www.epa.gov/glnpo/atlas/index.html

2 U.S. Environmental Protection Agency and Environment Canada, 2009. State of the Great Lakes 2009 Highlights. Available from: http://binational.net/solec/sogl2009/sogl_2009_h_en.pdf; Hjartarson, J., Mendelsohn, M., Bramwell, A., and Hintonet, K., 2011. The Vital Commons: An Agenda for the Great Lakes - St. Lawrence Region. Available from: http://www.greatlakessummit.org/wp-content/uploads/2011/03/The%20Vital%20Commons_digital.pdf.

3 National Oceanic and Atmospheric Administration, 2010. Coastal Zone Management Act Performance Measurement System: 2010 Report on Contextual Indicators. Available from: http://coastalmanagement.noaa.gov/success/media/contextualindicator2010.pdf

4 Government of Canada and U.S. Environmental Protection Agency, 1995, *supra* note 1.

5 U.S. Fish and Wildlife Service, 2011. Endangered Species Program in the Upper Midwest. See http://www.fws.gov/midwest/endangered/lists/cty_indx.html for species lists.

6 World Business Chicago, 2011. Great Lakes St. Lawrence Economic Region Profile. Available from: http://www.worldbusinesschicago.com/files/data/GLSL_Economy_Update_2011%20(2009%20data)_1.pdf

7 Vaccaro, L., and Read, J., 2011. Vital to our Nation's Economy: Great Lakes Jobs Report 2011. Michigan Sea Grant: Ann Arbor, MI. Available from: http://ww.miseagrant.umich.edu/economy

8 National Park Service, 2009. Find a Park. Available from: http://www.nps.gov/findapark/index.htm

9 Southwick Associates, 2007. Sportfishing in America: An Economic Engine and Conservation Powerhouse. Produced for the American Sportfishing Association with funding from the Multistate Conservation Grant Program. Available from: http://www.asafishing.org/images/statistics/resources/Sportfishing%20in%20America%20Rev.%207%2008.pdf

10 Great Lakes Commission, 2007. Great Lakes Recreational Boating's Economic Punch. Available from: http://www.glc.org/recboat/pdf/rec-boating-final-small.pdf

11 Vaccaro, L., and Read, J., 2011, *supra* note 7.

12 The Great Lakes Regional Collaboration Strategy, 2005. Available from: http://www.glrc.us/strategy.html

13 See state-specific fact sheets, Great Lakes Commission, 2011. Available from: http://www.glc.org/restore

14 Austin, J.C., Anderson, S., Courant, P.N., and Litan, R.E., 2007. Healthy Waters, Strong Economy: The Benefits of Restoring the Great Lakes Ecosystem. The Brookings Institution, Washington, D.C. Available from: http://www.brookings.edu/metro/pubs/20070904_gleiecosystem.pdf

15 Bails, J., Beeton, A., Bulkley, J., DePhilip, M., Gannon, J., Murray, M., Regier, H., and Scavia, D., Prescription for Great Lakes Ecosystem protection and restoration. Available from: http://www.healthylakes.org/site_upload/upload/prescriptionforgreatlakes.pdf.

16 Carlson, R.E., 1977. A trophic state index for lakes. Limnology and Oceanography 22, 361-369; Carlson, R.E., and Simpson, J., 1996. A Coordinator's Guide to Volunteer Lake Monitoring Methods. North American Lake Management Society. Available from: http://www.secchidipin.org/tsi.htm

17 Schindler, D.W., 1974. Eutrophication and recovery in experimental lakes: implications for lake management. Science 184, 897-899; Schindler, D.W., 1977. Evolution of phosphorus limitation in lakes. Science 195, 260-262; Correll, D.L., 1998. The role of phosphorus in the eutrophication of receiving waters: A review. Journal of Environmental Quality 27, 261-266

18 Carlson, R.E., and Simpson, J., 1996, *supra* note 16.

19 Patalas, K., 1972. Crustacean plankton and eutrophication of St. Lawrence Great Lakes. Journal of the Fisheries Research Board of Canada 29, 1451-1462; Dobson, H.F.H., Gilberts M., and Sly, P.G., 1974. Summary and comparison of nutrients and related water-quality in lakes Erie, Ontario, Huron, and

Superior. Journal of the Fisheries Research Board of Canada 31, 731-738; Vollenweider, R.A., Munawar, M., and Stadelmann, P., 1974. A comparative review of phytoplankton and primary production in the Laurentian Great Lakes. Journal of the Fisheries Research Board of Canada 31, 739–762; Munawar, M., and Munawar, I.F., 1982. Phycological studies in lakes Ontario, Erie, Huron, and Superior. Canadian Journal of Botany 60, 1837- 1858; Beeton, A.M., and Saylor, J.H., 1995. Limnology of Lake Huron. In: Munawar, M., Edsall, T., and Leach, J. (Eds.), The Lake Huron ecosystem: ecology, fisheries, and management. Ecovision World Monograph Series, SPB Academic Publ., Amsterdam, pp. 1-37.

20 Patalas, K., 1972, *supra* note 19; Dobson et al. 1974, *supra* note 19; Vollenweider et al. 1974, *supra* note 19; Munawar and Munawar 1982, *supra* note 19.

21 Vollenweider et al. 1974, *supra* note 19; Beeton and Saylor 1995, *supra* note 19.

22 Beeton, A.M., and Edmonson, W.T., 1972. The eutrophication problem. Journal of the Fisheries Research Board of Canada 19, 673-682.

23 Stoermer, E.F., Wolin, J.A., and Schelske, C.L., 1993. Paleolimnological comparison of the Laurentian Great Lakes based on diatoms. Limnology and Oceanography 38, 1311-1316.

24 International Joint Commission, 1970. Pollution of Lake Erie, Lake Ontario, and the international section of the St. Lawrence River. International Joint Commission, Washington, D.C., and Ottawa, Ontario. Available from: http://www.ijc.org/php/publications/pdf/ID364.pdf; DePinto, J.V., Young, T.C., and McIlroy, L.M., 1986. Great Lakes water quality improvement. Environmental Science and Technology 20, 752-759; Carpenter, S.R., Caraco, N.F., Correll, D.L., Howarth, R.W., Sharpley, A.N., and Smith, V.H., 1998. Nonpoint pollution of surface waters with phosphorus and nitrogen. Ecological Applications 8, 559-568; Correll, D.L., 1998, *supra* note 16.

25 Carpenter et al. 1998, *supra* note 24; Watson, S.B., Ridal, J., and Boyer, G.L., 2008. Taste and odour and cyanobacterial toxins: Impairment, prediction, and management in the Great Lakes. Canadian Journal of Fisheries and Aquatic Sciences 65, 1779–1796.

26 International Joint Commission, 1980. Phosphorus management for the Great Lakes: Final report of the Phosphorus Management Strategies Task Force. International Joint Commission, Washington, D.C., and Ottawa, Ontario; Higgins, S.N., Malkin, S.Y., Howell, E.T., Guildford, S.J., Campbell, L., Hiriart-Baer, V., and Hecky, R.E., 2008. An ecological review of *Cladophora glomerata* (Chlorophyta) in the Laurentian Great Lakes. Journal of Phycology 44, 839-854; Auer, M.T., Tomlinson, L.M., Higgins, S.N., Malkin, S.Y., Howell, E.T., and Bootsma, H.A., 2010. Great Lakes Cladophora in the 21st century: Same algae—different ecosystem. Journal of Great Lakes Research 36, 248-255.

27 DePinto et al. 1986, *supra* note 24.

28 Carpenter et al. 1998, *supra* note 24; Correll, D.L., 1998, *supra* note 17.

29 IJC 1980, *supra* note 26; Ludsin, S.A., Kershner, M.W., Blocksom, K.A., Knight, R.L., and Stein, R.A., 2001. Life after death in Lake Erie: Nutrient controls drive fish species richness, rehabilitation. Ecological Applications 11, 731-746.

30 Eshenroder, R.L., and Burnham-Curtis, M.K., 1999. Species succession and sustainability of the Great Lakes fish community. In: Taylor, W.W., and Ferreri, C.P. (Eds.), Great Lakes Fishery Policy and Management: A Binational Perspective. The Michigan State University Press, East Lansing, MI, pp. 145-184.

31 Regier, H.A., and Hartman, W.L., 1973. Lake Erie's fish community: 150 years of cultural stresses. Science 180, 1248-1255; Jude, D.J., and Tesar, F.J., 1985. Recent changes in the inshore forage fish of Lake Michigan. Canadian Journal of Fisheries and Aquatic Sciences 42, 1154-1157; Bence, J.R., and Smith, K.D., 1999. An overview of recreational fisheries of the Great Lakes. In: Taylor, W.W., and Ferreri, C.P. (Eds.), Great Lakes Fishery Policy and Management: A Binational Perspective. The Michigan State University Press, East Lansing, MI, pp. 259-306; Nepszy, S.J., 1999. The changing fishery regime in Lake Erie. In: Munawar, M., Edsall, T., and Munawar, I.F. (Eds.), State of Lake Erie: Past, present and future. Backhuys Publishers, Leiden, the Netherlands, pp. 233-239; Mills, E.L., Casselman, J.M., Dermott, R., Fitzsimons, J.D., Gal, G., Holeck, K.T., Hoyle, J.A., Johannsson, O.E., Lantry, B.F., Makarewicz, J.C., Millard, E.S., Munawar, I.F., Munawar, M., O'Gorman, R., Owens, R.W., Rudstam, L.G., Schaner, T., and Stewart, T.J., 2003. Lake Ontario: Food web dynamics in a changing ecosystem (1970-2000). Canadian Journal of Fisheries and Aquatic Sciences 60, 471-490.

32 Cook, D.G., and Johnson, M.G., 1974. Benthic macroinvertebrates of the St. Lawrence Great Lakes. Journal of the Fisheries Research Board of Canada 31, 763–782.

33 Scott, W.B., and Crossman, E.J., 1973. Freshwater fishes of Canada. Bulletin of the Fisheries Research Board of Canada 184, Department of the Environment, Ottawa, ON; Wells, L., 1980. Food of alewives, yellow perch, spottail shiners, trout-perch, and slimy and fourhorn sculpins in southeastern Lake Michigan. U.S. Fish and Wildlife Service Technical Report 98, Ann Arbor, MI.

34 IJC 1980, *supra* note 26.

35 IJC 1980, *supra* note 26; Krieger, K.A., Schloesser, D.W., Manny, B.A., Trisler, C.E., Heady, S.E., Ciborowski, J.J.H., and Muth, K.M., 1996. Recovery of burrowing mayflies (Ephemeroptera: Ephemeridae: *Hexagenia*) in western Lake Erie. Journal of Great Lakes Research 22, 254-263.

36 DePinto et al. 1986, *supra* note 24.

37 *Id.*

38 DePinto et al. 1986, *supra* note 24; Millard, E.S., Johannsson, O.E., Nielson, M.A., and El-Shaarawi, A.H., 2003. Long-term seasonal and spatial trends in nutrients, chlorophyll *a* and light attenuation in Lake Ontario. In: Munawar, M. (Ed.), State of Lake Ontario: Past, present, and future. Ecovision World Monograph Series, Aquatic Ecosystem Health and Management Society, pp. 97-132.

39 Lesht, B.M., Fontaine, T.D., and Dolan, D.M., 1991. Great Lakes total phosphorus model: Post audit and regionalized sensitivity analysis. Journal of Great Lakes Research 17, 3-17.

40 DePinto et al. 1986, *supra* note 24.

41 Neilson M., L'Italien, S., Glumac, V., Williams, D., and Bertram, P., 1995. State of the Lakes Ecosystem Conference Background Paper. Nutrients: Trends and system response. U.S. Environmental Protection Agency, Chicago, IL and Environment Canada, Burlington, ON. Available from: http://www.epa.gov/solec/archive/1994/1994_Nutrients%20_%20Trends_and_System-Response.pdf; Charlton, M.N., Le Sage R., and Milne, J.E., 1999. Lake Erie in transition: The 1990's. In: Munawar, M., Edsall, T., and Munawar, I.F. (Eds.), State of Lake Erie: Past, present and future. Backhuys Publishers, Leiden, the Netherlands, pp. 97-123.

42 Dolan, D.M., 1993. Point source loadings of phosphorus to Lake Erie: 1986-1990. Journal of Great Lakes Research 19, 212-223; Matisoff, G., and Ciborowski, J.J.H., 2005. Lake Erie Trophic Status Collaborative Study. Journal of Great Lakes Research 31 (Suppl. 2), 1-10.

43 Millard et al. 2003, *supra* note 38; Evans, M.E., Fahnenstiel, G., and Scavia, D., 2011. Incidental oligotrophication of North American Great Lakes. Environmental Science and Technology 45, 3297-3303.

44 Dove, A., 2009. Long-term trends in major ions and nutrients in Lake Ontario. Aquatic Ecosystem Health and Management 12, 281–295.

45 Charlton et al. 1999, *supra* note 41.

46 Munawar, M., and Munawar, I.F., 1999. The changing phytoplankton biomass and its composition in Lake Erie: A lake wide comparative analysis. In: Munawar, M., Edsall, T., and Munawar, I.F. (Eds.), State of Lake Erie: Past, present and future. Backhuys Publishers, Leiden, the Netherlands, pp. 125-154.

47 See for example Bierman, V.J., Dolan, D.M., and Kasprzyk, R., 1984. Retrospective analysis of the response of Saginaw Bay, Lake Huron, to reductions in phosphorus loadings. Environmental Science and Technology 18, 23-31.

48 Auer et al. 2010, *supra* note 26.

49 Makarewicz, J.C., and Bertram, P., 1991. Evidence for the restoration of the Lake Erie ecosystem. BioScience 41, 216-223; Makarewicz, J.C., 1993. Phytoplankton biomass and species composition in Lake Erie, 1970 to 1987. Journal of Great Lakes Research 19, 258-274; Stoermer, E.F., Emmert, G., Julius, M.L., and Schelske, C.L., 1996. Paleolimnologic evidence of rapid recent change in Lake Erie's trophic status. Canadian Journal of Fisheries and Aquatic Sciences 53, 1451-1458; Johannsson, O.E., Graham, D.M., Einhouse, D.W.E., and Mills, E.L., 1999. Historical and recent changes in the Lake Erie zooplankton community and their relationship to ecosystem function. In: Munawar, M., Edsall, T., and Munawar, I.F. (Eds.), State of Lake Erie: Past, present and future. Backhuys Publishers, Leiden, the Netherlands, pp. 169-196; Johannsson, O.E., 2003. A history of changes in zooplankton community structure and function in Lake Ontario: Responses to whole-lake remediation and exotic invasions. In: Munawar, M. (Ed.), State of Lake Ontario: Past, present, and future. Ecovision World Monograph Series, Aquatic Ecosystem Health and Management Society, pp. 221-256.

50 Krieger et al. 1996, *supra* note 35; Edsall, T.A., Madenjian, C.P., and Manny, B.A., 1999. Burrowing mayflies in Lake Erie – a review. In: Munawar, M., Edsall, T., and Munawar, I.F. (Eds.), State of Lake Erie: Past, present and future. Backhuys Publishers, Leiden, the Netherlands, pp. 219-231.

51 Gopalan, G., Culver, D.A., Wu, L., and Trauben, B.K., 1998. Effects of recent ecosystem changes on the recruitment of young-of-the-year fish in western Lake Erie. Canadian Journal of Fisheries and Aquatic Sciences 55, 2572-2579.

52 Ludsin et al. 2001, *supra* note 29.

53 For a more detailed discussion of the impacts of invasive species up to 2004, please see White, G., Murray, M., and Jackson, S.E., 2004. Ecosystem Shock: The Devastating Impacts of Invasive Species on the Great Lakes Food Web. National Wildlife Federation. Available from: http://www.nwf.org/~/media/PDFs/Wildlife/EcosystemShock.ashx

54 For discussion and examples, see Stoermer et al. 1993, *supra* note 23; Nalepa, T.F., Hartson, D.J., Fanslow, D.L., Lang, G.A., and Lozano, S.J., 1998. Declines in benthic macroinvertebrate populations in southern Lake Michigan, 1980-1993. Canadian Journal of Fisheries and Aquatic Sciences 55, 2402-2413; Charlton et al. 1999, *supra* note 41; Nicholls, K.H., Standke, S.J., and Nepszy, G.J., 1999. Effects of dreisseneid mussles on nitrogen and phosphorus in north shore waters of Lake Erie. In: Munawar, M., Edsall, T., and Munawar, I.F. (Eds.), State of Lake Erie: Past, present and future. Backhuys Publishers, Leiden, the Netherlands, pp. 323-336; Munawar, M., and Munawar, I.F., 2003. In: Munawar, M. (Ed.), State of Lake Ontario: Past, present, and future. Ecovision World Monograph Series, Aquatic Ecosystem Health and Management Society, pp. 187-219; Depew, D.C., Guildford, S.J., and Smith, R.E.H., 2006. Nearshore-offshore comparison of chlorophyll *a* and phytoplankton production in the dreissenid-colonized eastern basin of Lake Erie. Canadian Journal of Fisheries and Aquatic Sciences 63, 1115-1129.

55 Mills, E.L., Leach, J.H., Carlton, J.T., and Secor, C.L., 1994. Exotic species and the integrity of the Great Lakes: Lessons from the past. Bioscience 44, 666-676; Eshenroder and Burnham-Curtis 1999, *supra* note 30.

56 See for example Cook, P.M., Robbins, J.A., Endicott, D.D., Lodge, K.B., Guiney, P.D., Walker, M.K., Zabel, E.W., and Peterson, R.E., 2003. Effects of aryl hydrocarbon receptor-mediated early life stage toxicity on lake trout populations in Lake Ontario during the 20th century. Environmental Science and Technology 37, 3864-3877.

57 Mills et al. 1994, *supra* note 55; Eshenroder and Burnham-Curtis 1999, *supra* note 30.

58 Fuller, P., Maynard, E., and Raikow, D., 2011. Alosa *pseudoharengus*. U.S. Geological Survey Nonindigenous Aquatic Species Database, Gainesville, FL. Available from: http://nas.er.usgs.gov/queries/FactSheet.aspx?SpeciesID=490. Revised 9/24/2009.

59 Eshenroder and Burnham-Curtis 1999, *supra* note 30.

60 Mills et al. 1994, *supra* note 55; Eshenroder and Burnham-Curtis 1999, *supra* note 30.

61 Eshenroder and Burnham-Curtis 1999, *supra* note 30; Leach, J.H., Mills, E.L., and Dochoda, M.R., 1999. Non-indigenous species in the Great Lakes: Ecosystem impacts, binational policies, and management. In: Taylor, W.W., and Ferreri, C.P. (Eds.), Great Lakes Fishery Policy and Management: A Binational Perspective. The Michigan State University Press, East Lansing, MI, pp. 185-207.

62 Mills et al. 1994, *supra* note 55; Eshenroder and Burnham-Curtis 1999, *supra* note 30; Madenjian, C.P., Fahnenstiel, G.L., Johengen, T.H., Nalepa, T.F., Vanderploeg, H.A., Fleischer, G.W., Schneeberger, P.J., Benjamin, D.M., Smith, E.B., Bence, J.R., Rutherford, E.S., Lavis, D.S., Robertson, D.M., Jude, D.J., and Ebener, M.P., 2002. Dynamics of the Lake Michigan food web, 1970-2000. Canadian Journal of Fisheries and Aquatic Sciences 59, 736-753; Mills et al. 2003, *supra* note 31.

63 Bence and Smith 1999, *supra* note 31; Eshenroder and Burnham-Curtis 1999, *supra* note 30; Madenjian et al. 2002, *supra* note 62; Mills et al. 2003, *supra* note 31.

64 Eshenroder and Burnham-Curtis 1999, *supra* note 30.

65 Bence and Smith 1999, *supra* note 31; Nepszy 1999, *supra* note 31.

66 Jude and Tesar 1985, *supra* note 31; Madenjian et al. 2002, *supra* note 62; Mills et al. 2003, *supra* note 31.

67 Jude, D.J., Reider, R. H., and Smith, G. R., 1992. Establishment of Gobiidae in the Great Lakes Basin. Canadian Journal of Fisheries and Aquatic Sciences. 49, 416-421.

68 Charlebois, P.M., Corkum, L.D., Jude, D.J., and Knight, C., 2001. The round goby (*Neogobius melanostomus*) invasion: Current research and future needs. Journal of Great Lakes Research 27, 263-266.

69 Janssen, J., and Jude, D.J., 2001. Recruitment failure of mottled sculpin *Cottus bairdi* in Calumet Harbor, southern Lake Michigan, induced by the newly introduced round boby *Neogobius melanostomus*. Journal of Great Lakes Research 27, 319-328.

70 Bronte, C.R., Evrard, L.M., Brown, W.P., Mayo, K.R., and Edwards, A.J., 1998. Fish community changes in the St. Louis River estuary, Lake Superior, 1989-1996: Is it ruffe or population dynamics? Journal of Great Lakes Research 24, 309-318.

71 Fuller, P., and Jacobs, G., 2011. *Gymnocephalus cernuus*. U.S. Geological Survey Nonindigenous Aquatic Species Database, Gainesville, FL. Available from: http://nas.er.usgs.gov/queries/FactSheet.aspx?SpeciesID=7. Revised 8/25/2011.

72 Mills et al. 1994, *supra* note 55.

73 Vanderploeg, H.A., Nalepa, T.F., Jude, D.J., Mills, E.L., Holeck, K.T., Liebig, J.R., Grigorovich, I.A., and Ojaveer, H., 2002. Dispersal and emerging ecological impacts of Ponto-Caspian species in the Laurentian Great Lakes. Canadian Journal of Fisheries and Aquatic Sciences 59, 1209-1228.

74 Hebert, P.D.N., Muncaster, B.W., and Mackie, G.L., 1989. Ecological and genetic studies on *Dreissena polymorpha* (Pallas): A new mollusc in the Great Lakes. Canadian Journal of Fisheries and Aquatic Sciences 46: 1587-1591; May, B., and Marsden, J.E., 1992. Genetic identification and implications of another invasive species of dreissenid mussel in the Great Lakes. Canadian Journal of Fisheries and Aquatic Sciences 59, 1209-1228.

75 Vanderploeg et al. 2002, *supra* note 73.

76 Jarvis, P.J., Dow, J., Dermott, R., and Bonnell, R., 2000. Zebra (*Dreissena polymorpha*) and quagga mussel (*Dreissena bugensis*) distribution and density in Lake Erie, 1992-1998. Canadian Technical Report of Fisheries and Aquatic Sciences No. 2304; Johannsson, O.E., Dermott, R., Graham, D.M., Dahl, J.A., Millard, E.S., Myles, D.D., and LeBlanc, J., 2000. Benthic and pelagic secondary production in Lake Erie after the invasion of *Dreissena* spp. with implications for fish production. Journal of Great Lakes Research 26, 31-54; Nalepa, T.F., Fanslow, D.L., Pothoven, S.A., Foley, A.J., and Lang, G.A., 2007. Long-term trends in benthic macroinvertebrate populations in Lake Huron over the past four decades. Journal of Great Lakes Research 33, 421-436; Watkins, J.M., Dermott, R., Lozano, S.J., Mills, E.L., Rudstam, L.G., and Scharold, J.V., 2007. Evidence for remote effects of dreissenid mussels on the amphipod *Diporeia*: Analysis of Lake Ontario benthic surveys, 1972–2003. Journal of Great Lakes Research 33, 642-657; Dermott, R., and Dow, J., 2008. Changing benthic fauna of Lake Erie between 1993 and 1998. In: Munawar, M., and Heath, R. (Eds.), Checking the Pulse of Lake Erie. Ecovision World Monograph Series, Aquatic Ecosystem Health and Management Society, pp. 409-438; Nalepa, T.F., Fanslow, D.L., and Lang, G.A., 2009. Transformation of the offshore benthic community in Lake Michigan: Recent shift from the native amphipod *Diporeia* spp. to the invasive mussel *Dreissena rostriformis bugensis*. Freshwater Biology 54, 466–479; Nalepa, T.F., Fanslow, D.L., and Pothoven, S.A., 2010. Recent changes in density, biomass, recruitment, size structure, and nutritional state of *Dreissena* populations in southern Lake Michigan. Journal of Great Lakes Research 36, 5-19.

77 Alexander, J. April 15 2011. Quagga mussels: 950 trillion tiny time bombs in our lakes? *Muskegon Chronicle*. Available from: http://www.mlive.com/outdoors/index.ssf/2011/04/quagga_mussels_950_trillion_ti.html

78 Vanderploeg et al. 2002, *supra* note 73.

79 Fahnenstiel, G.L., Lang, G.A., Nalepa, T.F., and Johengen, T.H., 1995. Effects of zebra mussel (*Dreissena polymorpha*) colonization on water quality parameters in Saginaw Bay, Lake Huron. Journal of Great Lakes Research 21, 435-448; Heath, R.T., Fahnenstiel, G.L., Gardner, W.S., Cavaletto, J.F., and Hwang, S., 1995. Ecosystem-level effects of zebra mussels (*Dreissena polymorpha*): An enclosure experiment in Saginaw Bay, Lake Huron. Journal of Great Lakes Research 21, 501-516; Holland, R.E., Johengen, T.H., and Beeton, A.M., 1995. Trends in nutrient concentrations in hatchery bay, western Lake Erie, before and after *Dreissena polymorpha*. Canadian Journal of Fisheries and Aquatic Sciences 52, 1202-1209; Depew et al. 2006, *supra* note 54; Vanderploeg et al. 2002, *supra* note 73.

80 Fahnenstiel et al. 1995, *supra* note 79; Heath et al. 1995, *supra* note 79; Holland et al. 1995, *supra* note 79; Vanderploeg et al. 2002, *supra* note 73; Higgins, S.N., and Vander Zanden M.J., 2010. What a difference a species makes: A meta-analysis of dreissenid mussel impacts on freshwater ecosystems. Ecological Monographs 80, 179–196.

81 Johengen, T.H., Nalepa, T.F., Fahnenstiel, G.L., and Goudy, G., 1995. Nutrient changes in Saginaw Bay, Lake Huron, after the establishment of the zebra mussel (*Dreissena polymorpha*). Journal of Great Lakes Research 21, 449-464; Arnott, D.L., and Vanni, M.J., 1996. Nitrogen and phosphorus recycling by the zebra mussel (*Dreissena polymorpha*) in the western basin of Lake Erie. Canadian Journal of Fisheries and Aquatic Sciences 53, 646-659.

82 Bruesewitz, D.A., Tank, J.L., and Bernot, M.J., 2008. Delineating the effects of zebra mussels (*Dreissena polymorpha*) on N transformation rates using laboratory mesocosms. Journal of the North American Benthological Society 27, 236-251.

83 Schindler 1974, *supra* note 17; Schindler 1977, *supra* note 17; Correll, D.L., 1998, *supra* note 17.

84 Johengen et al. 1995, supra note 81; Vanderploeg et al. 2002, *supra* note 73.

85 Johengen et al. 1995, *supra* note 81; Charlton et al. 1999, *supra* note 41; Nicholls et al. 1999, *supra* note 54; Lam, D.C.L., Schertzer, W.M., McCrimmon, R.C., Charlton, M., and Millard, S., 2008. Modelling phosphorus and dissolved oxygen conditions pre- and post-dreissena arrival in Lake Erie. In: Munawar, M., and Heath, R. (Eds.), Checking the Pulse of Lake Erie. Ecovision World Monograph Series, Aquatic Ecosystem Health and Management Society, pp. 97-121.

86 Nalepa, T.F., NOAA Great Lakes Environmental Research Laboratory, personal communication, 1 Sept 2011.

87 Brown, M.K., Aguilar, C., and Cuhel, R., 2011. Particulate phosphorus content in the tissue of quagga mussels and water column biomass in distinct areas of Lake Michigan [Abstract]. American Society for Limnology and Oceanography Aquatic Sciences Meeting, 12-18 February 2011, San Juan, Puerto Rico. Available from: http://www.sgmeet.com/aslo/sanjuan2011/viewabstract2.asp?AbstractID=7983

88 Dove, A., and Warren, G., 2011. Draft State of the Lakes Ecosystem Conference 2011 Indicator Report: Nutrient Concentrations. U.S. Environmental Protection Agency, Chicago, IL and Environment Canada, Burlington, ON.

89 Johengen et al. 1995, *supra* note 81; Vanderploeg et al. 2002, *supra* note 73; Hecky, R.E., Smith. R.E.H., Barton, D.R., Guildford, S.J., Taylor, W.D., Charlton, M.N., and Howell, T., 2004. The nearshore phosphorus shunt: A consequence of ecosystem engineering by dreissenids in the Laurentian Great Lakes. Canadian Journal of Fisheries and Aquatic Sciences 61, 1285-1293; Ozersky, T., Malkin, S.Y., Barton, D.R., and Hecky, R.E., 2009. Dreissenid phosphorus excretion can sustain *C. glomerata* growth along a portion of Lake Ontario shoreline. Journal of Great Lakes Research 35, 321-328; Turner, C.B., 2010. Influence of zebra (*Dreissena polymorpha*) and quagga (*Dreissena rostriformis*) mussel invasions on benthic nutrient and oxygen dynamics. Canadian Journal of Fisheries and Aquatic Sciences 67, 1899-1908.

90 Fishman, D.B., Adlerstein, S.A., Vanderploeg, H.A., Fahnenstiel, G.L., and Scavia, D., 2009. Causes of phytoplankton changes in Saginaw Bay, Lake Huron, during the zebra mussel invasion. Journal of Great Lakes Research 35, 482-495; Fishman, D.B., Adlerstein, S.A., Vanderploeg, H.A., Fahnenstiel, G.L., and Scavia, D., 2010. Phytoplankton community composition of Saginaw Bay, Lake Huron, during the zebra mussel (*Dreissena polymorpha*) invasion: A multivariate analysis. Journal of Great Lakes Research 36, 9-19.

91 Hecky et al. 2004, *supra* note 89.

92 Hecky et al. 2004, *supra* note 89; Higgins, S.N., Howell, E.T., Hecky, R.E., Guildford, S.J., and Smith, R.E., 2005. The wall of green: The status of *Cladophora glomerata* on the northern shores of Lake Erie's eastern basin, 1995–2002. Journal of Great Lakes Research 31, 547-563; Higgins et al. 2008, *supra* note 26; Ozersky et al. 2009, *supra* note 89.

93 Cha, Y., Stow, C.A., Nalepa, T.F., and Reckhow, K.H., 2011. Do invasive mussels restrict offshore phosphorus transport in Lake Huron? Environmental Science and Technology 45, 7226–7231.

94 Fahnenstiel et al. 1995, *supra* note 79; Lowe, R.L., and Pillsbury, R.W., 1995. Shifts in benthic algal community structure and function following the appearance of zebra mussels (*Dreissena polymorpha*) in Saginaw Bay, Lake Huron. Journal of Great Lakes Research 21, 558-566; Skubinna, J.P., Coon, T.G., and Batterson,

T.R., 1995. Increased abundance and depth of submersed macrophytes in response to decreased turbidity in Saginaw Bay, Lake Huron. Journal of Great Lakes Research 21, 476-488; Davies, J., and Hecky, R.E., 2005. Initial measurements of benthic photosynthesis and respiration in Lake Erie. Journal of Great Lakes Research 31 (Suppl. 2), 195-207.

95 Vanderploeg, H.A., Liebig, J.R., Carmichael, W.W., Agy, M.A., Johengen, T.H., Fahnenstiel, G.L., and Nalepa, T.F., 2001. Zebra mussel (*Dreissena polymorpha*) selective filtration promoted toxic *Microcystis* blooms in Saginaw Bay (Lake Huron) and Lake Erie. Canadian Journal of Fisheries and Aquatic Sciences 58, 1208-1221; Vanderploeg et al. 2002, *supra* note 73; Fishman et al. 2009, *supra* note 90.

96 Heath et al. 1995, *supra* note 79; Arnott and Vanni 1996, *supra* note 81.

97 Campbell, L.M., Thacker, R., Barton, D., Muir, D.C.G., Greenwood, D., and Hecky, R.E., 2009. Re-engineering the eastern Lake Erie littoral food web: The trophic function of non-indigenous Ponto-Caspian species. Journal of Great Lakes Research 35, 224-231.

98 Nalepa et al. 1998, *supra* note 54; Lozano, S.J., Scharold, J.V., and Nalepa, T.F., 2001. Recent declines in benthic macroinvertebrate densities in Lake Ontario. Canadian Journal of Fisheries and Aquatic Sciences 58, 518-529; Madenjian et al. 2002, *supra* note 62; Nalepa, T.F., Fanslow, D.L., Foley, A.J., Lang, G.A., Eadie, B.J., and Quigley, M.A., 2006. Continued disappearance of the benthic amphipod *Diporeia* spp. in Lake Michigan: Is there evidence for food limitation? Canadian Journal of Fisheries and Aquatic Sciences 63, 872-890; Nalepa et al. 2007, *supra* note 76; Watkins et al. 2007, *supra* note 76; Nalepa et al. 2009, *supra* note 76; Barbiero, R.P., Schmude, K., Lesht, B.M., Riseng, C.M., Warren, G.J., and Tuchman, M.L., 2011. Trends in *Diporeia* populations across the Laurentian Great Lakes, 1997–2009. Journal of Great Lakes Research 37, 9-17.

99 Scott and Crossman 1973, *supra* note 33; Wells 1980, *supra* note 33; Cook and Johnson 1974, *supra* note 32; Nalepa, T.F., 1989. Estimates of macroinvertebrate biomass in Lake Michigan. Journal of Great Lakes Research 15, 437–443.

100 Watkins et al. 2007, *supra* note 76; Nalepa et al. 2007, *supra* note 76; Nalepa et al. 2009, *supra* note 76; Barbiero et al. 2011, *supra* note 98.

101 Barbiero et al. 2011, *supra* note 98.

102 Nalepa et al. 1998, *supra* note 54; Dermott, R., 2001. Sudden disappearance of the amphipod *Diporeia* from eastern Lake Ontario, 1993–1995. Journal of Great Lakes Research 27, 423-433; Nalepa et al. 2006, *supra* note 98.

103 Dermott, R., Munawar, M., Bonnell, R., Carou, S., Niblock, H., Nalepa, T.F., and Messick, G., 2005. Preliminary investigations for causes of the disappearance of *Diporeia* spp. from Lake Ontario. In: Mohr, L.C., and Nalepa, T.F. (Eds.), Proceedings of a Workshop on the Dynamics of Lake Whitefish (*Coregonus clupeaformis*) and the Amphipod *Diporeia* spp. in the Great Lakes. Great Lakes Fishery Commission Technical Report 66; Nalepa, T.F., Fanslow, D.L., Messick, G., 2005. Characteristics and potential causes of declining *Diporeia* spp. populations in southern Lake Michigan and Saginaw Bay, Lake Huron. In: Mohr, L.C., and Nalepa, T.F. (Eds.), Proceedings of a Workshop on the Dynamics of Lake Whitefish (*Coregonus clupeaformis*) and the Amphipod *Diporeia* spp. in the Great Lakes. Great Lakes Fishery Commission Technical Report 66

104 Lozano et al. 2001, *supra* note 98.; Mills et al. 2003, *supra* note 31.

105 Pothoven, S.A., and Madenjian, C.P., 2008. Changes in consumption by alewives and lake whitefish after dreissenid mussel invasions in lakes Michigan and Huron. North American Journal of Fisheries Management 28, 308-320.

106 Pothoven, S.A., Hondorp, D.W., and Nalepa, T.F., 2011. Declines in deepwater sculpin *Myoxocephalus thompsonii* energy density associated with the disappearance of *Diporeia* spp. in lakes Huron and Michigan. Ecology of Freshwater Fish 20, 14–22.

107 Pothoven, S.A., Nalepa, T.F., Schneeberger, P.J., and Brandt, S.B., 2001. Changes in diet and body condition of lake whitefish in southern Lake Michigan associated with changes in benthos. North American Journal of Fisheries Management 21, 876-883; Mohr, L.C., and Nalepa, T.F. (Eds.), Proceedings of a Workshop on the Dynamics of Lake Whitefish (Coregonus clupeaformis) and the Amphipod Diporeia spp. in the Great Lakes. Great Lakes Fishery Commission Technical Report 66; Pothoven, S.A., and Nalepa, T.F., 2006.

Feeding ecology of lake whitefish in Lake Huron. Journal of Great Lakes Research 32, 489-501; Pothoven and Madenjian 2008, *supra* note 105.

108 Fahnenstiel, G., Nalepa, T., Pothoven, S., Carrick, H., and Scavia, D., 2010. Lake Michigan lower food web: Long-term observations and *Dreissena* impact. Journal of Great Lakes Research 36, 1-4; Mida, J.L., Scavia, D., Fahnenstiel, G.L., Pothoven, S.A., Vanderploeg, H.A., and Dolan, D.M., 2010. Long-term and recent changes in southern Lake Michigan water quality with implications for present trophic status. Journal of Great Lakes Research 36, 42-49; Barbiero et al. 2011, *supra* note 98; Evans et al. 2011, *supra* note 40.

109 Evans et al. 2011, *supra* note 43.

110 *Id.*

111 Holeck, K.T., Watkins, J.M., Mills, E.L., Johannsson, O., Millard, S., Richardson, V., and Bowen, K., 2008. Spatial and long-term temporal assessment of Lake Ontario water clarity, nutrients, chlorophyll *a*, and zooplankton. Aquatic Ecosystem Health and Management 11, 377–391; Barbiero, R.P., Bunnell, D.B., Rockwell, D.C., and Tuchman, M.L., 2009. Recent increases in the large glacial-relict calanoid *Limnocalanus macrurus* in Lake Michigan. Journal of Great Lakes Research 35, 285-292; Barbiero et al. 2011, *supra* note 98.

112 Riley, S.C., Roseman, E.F., Nichols, S.J., O'Brien, T.P., Kiley, C.S., and Schaeffer, J.S., 2008. Deepwater demersal fish community collapse in Lake Huron. Transactions of the American Fisheries Society 137, 1879-1890.

113 Lake Huron Binational Partnership, 2008. 2008-2010 Action Plan. Available from: http://www.epa.gov/glnpo/lamp/lh_2008/lh_2008_8.pdf; Michigan Department of Natural Resources, 2010. Changes in Lake Huron's ecosystem and foodweb cause Chinook salmon collapse. Available from: http://www.michigan.gov/documents/LakeHuronNewEcosystem-foodweb_122463_7.pdf

114 Hecky et al. 2004, *supra* note 89; Higgins and Vander Zanden 2010, *supra* note 80.

115 Mellina, E., Rasmussen, J.B., and Mills, E.L., 1995. Impact of zebra mussel (*Dreissena polymorpha*) on phosphorus cycling and chlorophyll in lakes. Canadian Journal of Fisheries and Aquatic Sciences 52, 2553-2573; Nicholls et al. 1999, *supra* note 54; Hall, S.R., Pauliukonis, N.K., Mills, E.L., Rudstam, L.G., Schneider, C.P., Lary, S.J., and Arrhenius, F., 2003. A comparison of total phosphorus, chlorophyll *a*, and zooplankton in embayment, nearshore, and offshore habitats of Lake Ontario. Journal of Great Lakes Research 29, 54-69; Qualls, T.M., Dolan, D.M., Reed, T., Zorn, M.E., and Kennedy, J., 2007. Analysis of the impacts of the zebra mussel, *Dreissena polymorpha*, on nutrients, water clarity, and the chlorophyll-phosphorus relationship in lower Green Bay. Journal of Great Lakes Research 33, 617-626.

116 Vanderploeg et al. 2002, *supra* note 73.

117 Schloesser, D.W., Nalepa, T.F., and Mackie, G.L., 1996. Zebra mussel infestation of unionid bivalves (Unionidae) in North America. American Zoologist 36, 300-310; Vanderploeg et al. 2002, *supra* note 73.

118 Ricciardi, A., 2001. Facilitative interactions among aquatic invaders: Is an "invasional meltdown" occurring in the Great Lakes? Canadian Journal of Fisheries and Aquatic Sciences 58, 2513-2525; Vanderploeg et al. 2002, *supra* note 73.

119 Campbell et al. 2009, *supra* note 97; Madenjian, C.P., Pothoven, S.A.,Schneeberger, P.J., Ebener, M.P., Mohr, L.C., Nalepa, T.F., and Bence, J.R., 2010. Dreissenid mussels are not a "dead end" in Great Lakes food webs. Journal of Great Lakes Research 36, 73-77.

120 Pothoven et al. 2001, *supra* note 107; Mohr and Nalepa 2005, *supra* note 107; Pothoven et al. 2006, *supra* note 107; Pothoven and Madenjian 2008, *supra* note 105.

121 Benoit, H.P., Johannsson, O.E., Warner, D.M., Sprules, W.G., and Rudstam, L.G., 2002. Assessing the impact of a recent predatory invader: The population dynamics, vertical distribution, and potential prey of *Cercopagis pengoi* in Lake Ontario. Limnology and Oceanography 47, 626-635; Laxson, C.L., McPhedran, K.N., Makarewicz, J.C., Telesh, I.V., and MacIsaac, H.J., 2003. Effects of the non-indigenous cladoceran *Cercopagis pengoi* on the lower food web of Lake Ontario. Freshwater Biology 48, 2094-2106.

122 Barbiero, R.P., and Tuchman, M.L., 2004. Changes in the crustacean communities of lakes Michigan, Huron, and Erie following the invasion of the predatory cladoceran *Bythotrephes longimanus*. Canadian Journal of Fisheries and Aquatic Sciences 61, 2111-2125.

123 Bunnell, D.B., Davis, B.M., Warner, D.M., Chriscinske, M.A., and Roseman, E.F., 2011. Planktivory in the changing Lake Huron zooplankton community: *Bythotrephes* consumption exceeds that of *Mysis* and fish. Freshwater Biology 56, 1281-1296.

124 Johannsson, O.E., Bowen, K.L., Holeck, K.T., and Walsh, M.G., 2011. *Mysis diluviana* population and cohort dynamics in Lake Ontario before and after the establishment of *Dreissena* spp., *Cercopagis pengoi*, and *Bythotrephes longimanus*. Canadian Journal of Fisheries and Aquatic Sciences 68, 795-811.

125 Patalas, K., 1972, *supra* note 19; Watson, N.H.F., and Carpenter, G.F., 1974. Seasonal abundance of crustacean zooplankton and net plankton biomass of lakes Huron, Erie, and Ontario. Journal of the Fisheries Research Board of Canada 31,309-317.

126 Blossey, B., 2003. Phragmites: Common Reed. Cornell University Ecology and Management of Invasive Plants Program. Available from: http://www.invasiveplants.net/phragmites/

127 Wisconsin Dept. of Natural Resources, 2009. Reed canary grass (*Phalaris arundinacea*). Available from: http://dnr.wi.gov/invasives/fact/reed_canary.htm

128 Stackpoole, S., 1997. Purple Loosestrife in Michigan: Biology, Ecology, and Management. Michigan Sea Grant, Ann Arbor, MI, Bulletin E-2632. Available from: http://www.miseagrant.umich.edu/downloads/ais/fs-97-501_purple_loosestrife.pdf

129 Cao, L., 2011. *Potamogeton crispus*. U.S. Geological Survey Nonindigenous Aquatic Species Database, Gainesville, FL. Available from: http://nas.er.usgs.gov/queries/factsheet.aspx?SpeciesID=1134. Revised 8/9/2009.

130 Jude, D.J., and Pappas, J., 1992. Fish utilization of Great Lakes coastal wetlands. Journal of Great Lakes Research 18, 651-672. Wilcox N., D.A., 1995. The role of wetlands as nearshore habitat in Lake Huron. In: Munawar, M., Edsall, T., and Leach, J. (Eds.), The Lake Huron ecosystem: ecology, fisheries, and management. Ecovision World Monograph Series, SPB Academic Publ., Amsterdam, pp. 223-245.

131 Blossey, B., 2003, *supra* note 126.

132 Cao, L., 2011, *supra* note 129.

133 Environment Canada and U.S. Environmental Protection Agency, 2009. Coastal Wetland Plant Communities - Indicator #4862. State of the Great Lakes 2009. Cat. No. En161-3/1-2009E-PDF, pp. 249-254.

134 Ludyanskiy, M.L., McDonald, D., and MacNeill, D., 1993. Impact of the zebra mussel, a bivalve invader. Bioscience 43, 533-544.

135 U.S. Army Corps of Engineers Zebra Mussel Research Program, 2002. Economic impacts of zebra mussels. Zebra Mussel Information System. Available from: http://el.erdc.usace.army.mil/zebra/zmis/zmishelp/economic_impacts_of_zebra_mussel_infestation.htm

136 Ludyanskiy et al. 1993, *supra* note 134; Stop Aquatic Hitchhikers Campaign. Harmful Aquatic Hitchhikers: Mollusks: Zebra Mussel. Available from: http://www.protectyourwaters.net/hitchhikers/mollusks_zebra_mussel.php#affect

137 Lodge, D., and Finnoff, D., 2008. Annual Losses to Great Lakes Region by Ship-borne Invasive Species at least $200 Million. Center for Aquatic Conservation, University of Notre Dame, Notre Dame, IN.

138 Michigan Dept. of Natural Resources 2010, *supra* note 113.

139 Myerson, H. 17 April 2011. Red flags signal possible trouble for Lake Michigan salmon where chinooks are king. *The Grand Rapids Press*. Available from: http://www.mlive.com/outdoors/index.ssf/2011/04/in_lake_michigan_salmon_are_ki.html

140 Dolan, D.M., and McGunagle, K.P., 2005. Lake Erie total phosphorus loading analysis and update: 1996–2002. Journal of Great Lakes Research 31, 11-22; Dolan, D.M., and Richards, R.P., 2008. Analysis of late 90s phosphorus loading pulse to Lake Erie. In: Munawar, M., and Heath, R. (Eds.), Checking the Pulse of Lake Erie. Ecovision World Monograph Series, Aquatic Ecosystem Health and Management Society, pp.79-96.

141 Environment Canada and U.S. Environmental Protection Agency, 2009. Phosphorus Concentrations and Loadings, Indicator #111. State of the Great Lakes 2009. Cat. No. En161-3/1/2009E-PDF, pp. 77-81.

142 Environment Canada and U.S. Environmental Protection Agency, 2009, *supra* note 141; Dolan, D.M., and Chapra, S.C., 2011. Updating Great Lakes Total Phosphorus Loadings [Abstract]. International Association for Great Lakes Research 54th Annual Conference, 30 May – 3 June 2011, Duluth, MN. Available from: http://iaglr.org/conference/downloads/2011_abstracts.pdf

143 Dolan and Chapra, 2011, *supra* note 142.

144 Robertson, D.M., and Saad D.A., 2011. Nutrient inputs to the Laurentian Great Lakes by source and watershed estimated using SPARROW watershed models. Journal of the American Water Resources Association, doi: 10.1111/j.1752-1688.2011.00574.x. (Another potentially important point source of phosphorus loading is from Confined Animal Feeding Operations, or CAFOs. For more information on CAFOs, see: Sierra Club Michigan Chapter. Facts about CAFOs. Available from: http://michigan.sierraclub.org/issues/greatlakes/articles/cafofacts.html; U.S. Environmental Protection Agency National Pollutant Discharge Elimination System (NPDES), 2007. Animal Feeding Operations: Frequently Asked Questions. Available from: http://cfpub.epa.gov/npdes/faqs.cfm?program_id=7; U.S. Environmental Protection Agency National Pollutant Discharge Elimination System (NPDES), 2011. General Information on Concentrated Animal Feeding Operations. Available from: http://cfpub.epa.gov/npdes/afo/info.cfm?program_id=7)

145 Alexander, J., and Wallace, B., 2010. Turning the Tide: Investing in Wastewater Infrastructure to Create Jobs and Solve the Sewage Crisis in the Great Lakes. Healing Our Waters-Great Lakes Coalition. Available from: http://healthylakes.org/wordpress/wp-content/uploads/2010/08/08-02-2010HOWSewageReportFINAL.pdf; Great Lakes Commission and Great Lakes and St. Lawrence Cities Initiative, 2010. The Federal Wastewater Infrastructure Deficit in the Great Lakes Region. Available from: http://www.glc.org/announce/10/pdf/CitiesInvest-20100212-Final.pdf

146 Dyble, J. Phosphorus sources and impacts on water quality in Saginaw Bay. Michigan Dept. of Environmental Quality Saginaw Bay Coastal Initiative. Available from: http://www.michigan.gov/documents/deq/deq-ogl-SBCI-Phos-Sources-Impacts_232394_7.pdf; Ohio Environmental Protection Agency, 2010. Ohio Lake Erie Phosphorus Task Force Final Report. Available from: http://www.epa.ohio.gov/portals/35/lakeerie/ptaskforce/Task_Force_Final_Report_April_2010.pdf

147 Lake Erie Millennium Network Synthesis Team, 2011. Lake Erie Nutrient Loading And Harmful Algal Blooms: Research Findings and Management Implications. Available from: http://go.osu.edu/ts-060

148 Makarewicz, J.C., Bertram, P., and Lewis, T.W., 2000. Chemistry of the offshore surface waters of Lake Erie: Pre- and post-*Dreissena* introduction (1983–1993). Journal of Great Lakes Research 26, 82-93; Lake Erie Lakewide Management Plan (LaMP) Work Group, 2008. Lake Erie Lakewide Management Plan 2008. U.S. Environmental Protection Agency and Environment Canada. Available from: http://www.epa.gov/lamp/le_2008/index.html; Dove, A., 2009, *supra* note 44. Ohio Environmental Protection Agency 2010, *supra* note 146.

149 Johengen et al. 1995, *supra* note 81; Vanderploeg et al. 2002, *supra* note 73; Hecky et al. 2004, *supra* note 89; Ozersky et al. 2009, *supra* note 89; Turner et al. 2010, *supra* note 89.

150 Lake Erie Millennium Network Synthesis Team, 2011, *supra* note 147.

151 Ohio Environmental Protection Agency, 2010, *supra* note 146.

152 Charlton et al. 1999, *supra* note 41; Lake Erie LaMP Work Group, 2008, *supra* note 148.

153 Dove. A., and Warren, G., 2011, *supra* note 88.

154 *Id.*

155 *Id.*

156 *Id.*

157 Environment Canada and U.S. Environmental Protection Agency, 2009, *supra* note 141; Eutrophication Advisory Work Group to the International Joint Commission (IJC), 2009. Great Lakes Water Quality Agreement Priorities 2007-09 Series. Work Group Report on Eutrophication, 2009. IJC, Special Publication 2009-02, Windsor, Ontario, Canada. Available from: http://www.ijc.org/en/priorities/2009/reports/2009-eutrophication.pdf; Dove., A., and Warren., G., 2011, *supra* note 88.

158 Rockwell, D.C., Warren, G.J., Bertram, P.E., Salisbury, D.K., and Burns, N.M., 2005. The U.S. EPA Lake Erie Indicators Monitoring Program 1983-2002: Trends in phosphorus, silica, and chlorophyll *a* in the central basin. Journal of Great Lakes Research 31 (Suppl. 2), 23-34; Conroy, J.D., Kane, D.D., and Culver, D.A., 2008. In: Munawar, M., and Heath, R. (Eds.), Checking the Pulse of Lake Erie. Ecovision World Monograph Series, Aquatic Ecosystem Health and Management Society, pp. 369-408.

159 Ohio Environmental Protection Agency, 2010, *supra* note 146; Chaffin, J.D., Bridgeman, T.B., Heckathorn, S.A., and Mishra, S., 2011. Assessment of *Microcystis* growth rate potential and nutrient status across a trophic gradient in western Lake Erie. Journal of Great Lakes Research 37, 92-100.

160 The Associated Press. 29 August 2011. State strengthens its algae warning for Lake Erie beach. Available from: http://www.thenews-messenger.com/article/20110829/NEWS01/108290313/State-strengthens-its-algae-warning-Lake-Erie-beach

161 Brittain, S.M., Wang, J., Babcock-Jackson, L., Carmichael, W.W., Rinehart, K.L., and Culver, D.A., 2000. Isolation and characterization of microcystins, cyclic heptapeptide hepatotoxins from a Lake Erie strain of *Microcystis aeruginosa*. Journal of Great Lakes Research 26, 241-249; Murphy, T.P., Irvine, K., Guo, J., Davies, J., Murkin, H., Charlton, M., and Watson, S.B., 2003. New microcystin concerns in the lower Great Lakes. Water Quality Research Journal of Canada 38, 127-140; Oullette, A.J.A., Handy, S.M., and Wilhelm, S.W., 2006. Toxic *Microcystis* is widespread in Lake Erie: PCR detection of toxin genes and molecular characterization of associated cyanobacterial communities. Microbial Ecology 51, 154-165; Hotto, A.M., Satchwell, M.F., and Boyer, G.L., 2007. Molecular characterization of potential microcystin-producing cyanobacteria in Lake Ontario embayments and nearshore waters. Applied and Environmental Microbiology 73, 4570–4578.

162 Harmful Algal Blooms in Lake Erie: Experimental HAB Bulletin, 2011. Western Lake Erie Microcystin Samples. National Oceanic and Atmospheric Administration, Center of Excellence for Great Lakes and Human Health, Ann Arbor, MI. Available from: http://www.glerl.noaa.gov/res/Centers/HABS/western_lake_erie.html

163 Lake Erie Millennium Network Synthesis Team, 2011, *supra* note 147.

164 Higgins et al. 2005, *supra* note 92; Environment Canada and U.S. Environmental Protection Agency. 2009, *supra* note 141; Ohio Environmental Protection Agency, 2010, *supra* note 146.

165 Bridgeman, T.B., and Penamon, W.A., 2010. *Lyngbya wollei* in western Lake Erie. Journal of Great Lakes Research 36, 167-171.

166 Burns, N.M., Rockwell, D.C., Bertram, P.E., Dolan, D.M., and Ciborowski, J.J.H., 2005. Trends in temperature, Secchi depth, and dissolved oxygen depletion rates in the central basin of lake Erie, 1983-2002. Journal of Great Lakes Research 31 (Suppl. 2), 35-49; Hawley, N., Johengen, T.H., Rao, Y.R., Ruberg, S.A,. Beletsky, D., Ludsin, S.A., Eadie, B.J., Schwab, D.J., Croley, T.E., and Brandt, S.B., 2006. Lake Erie hypoxia prompts Canada-U.S. study. Eos 87, 313-324; Lake Erie Lakewide Management Plan Annual Report 2011. Available from: http://binational.net/lamp/le_ar_2011_en.pdf

167 Hawley et al. 2006, *supra* note 166.

168 *Id.*

169 Ohio Environmental Protection Agency, 2010, *supra* note 146.

170 Arend, K.K., Beletsky, D., DePinto, J.V., Ludsin, S.A., Roberts, J.J., Rucinski, D.K., Scavia, D., Schwab, D.J., and Höök, T.O., 2011. Seasonal and interannual effects of hypoxia on fish habitat quality in central Lake Erie. Freshwater Biology 56, 366-383.

171 Watson et al. 2008, *supra* note 25.

172 Byappanahalli, M.N., and Whitman, R.L., 2009. *Clostridium botulinum* type E occurs and grows in the alga *Cladophora glomerata*. Canadian Journal of Fisheries and Aquatic Sciences 66, 879-882.

173 Brittain et al. 2000, *supra* note 161; Watson et al. 2008, *supra* note 25.

174 Hunt, S. 2 August 2010. Algae may be killing pets. *The Columbus Dispatch*. Available from: http://www.dispatch.com/content/stories/local/2010/07/30/algae-may-be-killing-pets.html

175 Murphy et al. 2003, *supra* note 161.

176 Byappanahalli, M.N., Sawdey, R., Ishii, S., Shively, D.A., Ferguson, J.A., Whitman, R.L., and Sadowsky, M.J., 2009. Seasonal stability of *Cladophora*-associated *Salmonella* in Lake Michigan watersheds. Water Research 43, 806-814; Vanden Heuvel, A., McDermott, C., Pillsbury, R., Sandrin, T., Kinzelman, J., Ferguson, J., Sadowsky, M., Byappanahalli, M., Whitman, R., and Kleinheinz, G.T., 2010. The green alga, *Cladophora*, promotes *Escherichia coli* growth and contamination of recreational waters in Lake Michigan. Journal of Environmental Quality 39, 333-344; Verhougstraete, M.P., Byappanahalli, M.N., Rose, J.B., and Whitman, R.L., 2010. *Cladophora* in the Great Lakes: impacts on beach water quality and human health. Water Science and Technology 62, 68-76.

177 Schindler 1974, *supra* note 17; Schindler 1977, *supra* note 17; Correll, D.L., 1998, *supra* note 17.

178 Moon, J.B., and Carrick, H.J., 2007. Seasonal variation of phytoplankton nutrient limitation in Lake Erie. Aquatic Microbial Ecology 48, 61-71; North, R.L., Guildford, S.J., Smith, R.E.H., Havens, S.M., and Twiss, M.R., 2007. Evidence for phosphorus, nitrogen, and iron colimitation of phytoplankton communities in Lake Erie. Limnology and Oceanography 52, 315-328; Chaffin et al. 2011, *supra* note 159.
179 Lake Erie Millennium Network Synthesis Team, 2011, *supra* note 147; Chaffin et al. 2011, *supra* note 159.
180 Moon and Carrick 2007, *supra* note 178.
181 *Id.*
182 Heath et al. 1995, *supra* note 79.
183 Bierman, V.J., and Dolan, D.M., 1981. Modeling of phytoplankton-nutrient dynamics in Saginaw Bay, Lake Huron. Journal of Great Lakes Research 7, 409-439; Moon and Carrick 2007, *supra* note 178; North et al. 2007, *supra* note 178.
184 Hoagland, P., and Scatasta, S., 2006. The economic effects of harmful algal blooms. In: Granéli, E., and Turner, J. (Eds.), Ecology of Harmful Algae. Ecology Studies Series, Dordrecht, The Netherlands: Springer-Verlag, pp. 391-402.
185 Verhougstraete et al. 2010, *supra* note 176.
186 Rabinovici, S.J.M, Bernknopf, R.L., Wein, A.M., Coursey, D.L., and Whitman, R.L., 2004. Economic and health risk trade-offs of swim closures at a Lake Michigan beach. Environmental Science and Technology 38, 2737-2745.
187 Environment Canada and U.S. Environmental Protection Agency, 2009. Beach Advisories, Postings, and Closures - Indicator #4200. State of the Great Lakes 2009. Cat. No. En161-3/1-2009E-PDF, pp. 167-178.
188 Arend et al. 2011, *supra* note 170.
189 Southwick Associates, 2007, *supra* note 9.
190 Clean Water Act of 1972 § 303(d), 33 U.S.C. § 1313(d) (2010).
191 Government Accountability Office, 2005. Clean Water Act: Improved Resource Planning Would Help EPA Better Respond to Changing Needs and Fiscal Constraints. Available from: http://www.gao.gov/new.items/d05721.pdf
192 See for example U.S. Department of Agriculture, Natural Resources Conservation Service, 2008 NRCS Farm Bill Conservation Programs, available from: http://www.nrcs.usda.gov/programs/farmbill/; also see Olsen, K., 2007. Cultivating Restoration: How Farm Bill Conservation Programs Help Heal Our Great Lakes. Healing Our Waters – Great Lakes Coalition.
193 Pub. L. No. 111-88, Title II – Environmental Protection Agency (2009).
194 U.S. Environmental Protection Agency, 2010. Great Lakes Restoration Initiative Action Plan. Available from: http://greatlakesrestoration.us/pdfs/glri_actionplan.pdf
195 Ohio Environmental Protection Agency, 2010, *supra* note 146.
196 Kling, G.W., Hayhoe, K., Johnson, L.B., Magnuson, J.J., Polasky, S., Robinson, S.K., Shuter, B.J., Wander, M.M., Wuebbles, D.J., Zak, D.R., Lindroth, R.L., Moser, S.C., and Wilson, M.L., 2003. Confronting Climate Change in the Great Lakes Region: Impacts on our Communities and Ecosystems. Union of Concerned Scientists, Cambridge, Massachusetts, and Ecological Society of America, Washington, D.C. Available from: http://www.ucsusa.org/greatlakes/glchallengereport.html. (Note: some data are from 2005 updated Executive Summary.)
197 *Id.*
198 Kelleher, B. 12 August 2010. Lake Superior reaches record temp. *Minnesota Public Radio.* Available from: http://minnesota.publicradio.org/display/web/2010/08/12/warm-lake-superior/
199 NOAA Coastwatch, Great Lakes Node, 2011. Great Lakes Statistics. Available from: http://coastwatch.glerl.noaa.gov/statistic/statistic.html
200 Quinn, F.H., and Croley, T.E., 1999. Potential climate change impacts on Lake Erie. In: Munawar, M., Edsall, T., and Munawar, I.F. (Eds.), State of Lake Erie: Past, present and future. Backhuys Publishers, Leiden, the Netherlands, pp. 23-20; Kling et al. 2003, *supra* note 196.
201 Angel, J.R., and Kunkel, K.E., 2010. The response of Great Lakes water levels to future climate scenarios with an emphasis on Lake Michigan-Huron. Journal of Great Lakes Research 36, 51-58.
202 NOAA Great Lakes Environmental Research Laboratory, 2011. Great Lakes Water Level Observations. Available from: http://www.glerl.noaa.gov/data/now/wlevels/levels.html

203 Schertzer, W.M., Hamblin, P.F., and Lam, D.C.L., 2008. Lake Erie thermal structure: variability, trends and potential changes. In: Munawar, M., and Heath, R. (Eds.), Checking the Pulse of Lake Erie. Ecovision World Monograph Series, Aquatic Ecosystem Health and Management Society, pp. 3-44.

204 Quinn and Croley 1999, *supra* note 200; Kling et al. 2003, *supra* note 196.

205 Nicholls, K.H., 1999. Effects of temperature and other factors on summer phosphorus in the inner bay of Quinte, Lake Ontario: implications for climate warming. Journal of Great Lakes Research 25, 250-262.

206 Dolan and McGunagle 2005, *supra* note 140; Dolan and Richards 2008, *supra* note 140.

207 Great Lakes Commission and Great Lakes and St. Lawrence Cities Initiative, 2010, *supra* note 145.

208 Environment Canada and U.S. Environmental Protection Agency, 2009. Urban Density - Indicator #7000. State of the Great Lakes 2009. Cat. No. En161-3/1-2009E-PDF, pp. 259-263.

209 Environment Canada and U.S. Environmental Protection Agency, 2009. Ground Surface Hardening - Indicator #7054. State of the Great Lakes 2009. Cat. No. En161-3/1-2009E-PDF, pp. 281-285.

210 Environment Canada and U.S. Environmental Protection Agency, 2005. Coastal Wetland Area by Type - Indicator #4510. State of the Great Lakes 2005. Cat. No. En161-3/0-2005E-PDF, pp. 191-193.

211 Environment Canada and U.S. Environmental Protection Agency, 2009. Land Cover/Land Conversion - Indicator #7002. State of the Great Lakes 2009. Cat. No. En161-3/1-2009E-PDF, pp. 264-268.

212 *Id.*

213 Rowe, M.D., Pauer, J.J., Kreis, R.G., and Dolan, D.M., 2011. Response of nutrient concentrations and primary productivity in Lake Michigan to nutrient loading scenarios [Abstract]. International Association for Great Lakes Research 54th Annual Conference, 30 May – 3 June 2011, Duluth, MN. Available from: http://iaglr.org/conference/downloads/2011_abstracts.pdf; U.S. Environmental Protection Agency, 2011. Future Midwestern Landscapes Study. Available from: http://www.epa.gov/ecology/quick-finder/mid-west.htm

214 See Baker, E., Fusaro, A., and Sturtevant, R., 2011. Watchlist of Potential Great Lakes Aquatic Invasive Species. NOAA. Available from: http://www.glerl.noaa.gov/res/Programs/glansis/watchlist.html

215 Rasmussen, J.L., Regier, H.A., Sparks, R.E., and Taylor, W.W., 2011. Dividing the waters: The case for hydrologic separation of the North American Great Lakes and Mississippi River Basins. Journal of Great Lakes Research 37, 588-592; Veraldi, F.M., Baerwaldt, K., Herman, B., Herleth-King, S., Shanks, M., Kring, L., and Hannes, A., 2011. Non-Native Species of Concern and Dispersal Risk for the Great Lakes and Mississippi River Interbasin Study. U.S. Army Corps of Engineers. Available from: http://glmris.anl.gov/documents/docs/Non-Native_Species.pdf

216 United Press International. 2 June 2011. Study: Lake Erie could harbor Asian carp. Available from: http://www.upi.com/Science_News/2011/06/02/Study-Lake-Erie-could-harbor-Asian-carp/UPI-68211307041187/

217 Dizikes, C. 28 April 2011. Asian carp possibly hardier than once thought. *Chicago Tribune*. Available from: http://articles.chicagotribune.com/2011-04-28/news/ct-met-asian-carp-20110428_1_open-navigational-locks-locks-in-chicago-waterways-underwater-barrier

218 Ohio Environmental Protection Agency, 2010, *supra* note 146.

219 Similar recommendations have been made by others, including: Eutrophication Advisory Work Group to the International Joint Commission (IJC), 2009, *supra* note 157; Evans et al. 2011, *supra* note 43.

220 Some recommendations derive from Kidd, J., 2009. Workshop Report: Managing Watersheds for Great Lakes Benefits: Technical Workshop on Nutrients in the Nearshore. Prepared for Conservation Ontario. Available from: http://www.conservationontario.ca/great_lakes_workshop/PDF/Final_Full_Rprt_Mar_34_Techl_wrkshp.pdf

221 See U.S. Environmental Protection Agency, 2011. Lakewide Management Plans. Available from: http://www.epa.gov/greatlakes/lamp/

222 See Great Lakes Fishery Commission, Lake Committees. Available from: http://glfc.org/lakecom/

223 For an example of fisheries management practices changing in response to altered ecosystem regimes, see Michigan Dept. of Natural Resources Fisheries Division, 2011. Managing Chinook Salmon in Lake Huron:Current Findings and Proposed Management Options. Available from: http://www.michigan.gov/documents/dnr/Lake_Huron_Chinook_Management_Executive_Summary_359037_7.pdf.

224 Krist, F., Michigan Dept. of Natural Resources Lake Huron Citizens Fishery Advisory Committee, personal communication, 13 Sept 2011.

225 U.S. Environmental Protection Agency, 2010, *supra* note 194.

226 Pauer, J.J., Anstead, A.M., Melendez, W., Taunt, K.W., and Kreis, R.G., 2011. Revisiting the Great Lakes Water Quality Agreement phosphorus targets and predicting the trophic status of Lake Michigan. Journal of Great Lakes Research 37, 26-32.

227 See U.S. Environmental Protection Agency, 2011. Great Lakes Monitoring, Limnology Program. Available from: http://www.epa.gov/glnpo/monitoring/limnology/index.html

228 See U.S. Environmental Protection Agency, 2011. Office of Research and Development, Science Activities. Available from: http://www.epa.gov/ord/scievents/lakesci11/activities.htm#csmi

229 Johnson, J., 2011, Michigan Dept. of Natural Resources, personal communication, 12 September 2011.

230 Lake Erie Millennium Network Synthesis Team, 2011, *supra* note 147.

231 Chaffin et al. 2011, *supra* note 159.

232 U.S. Environmental Protection Agency, 2009. Nitrogen and Phosphorus Pollution Outreach Portal. Available from: http://www.hcdi.com/epa/np_outreachportal409/ed-resources.htm

233 Marrone Bio Innovations. Zequanox: A Green Solution to Control Destructive Mussels. Available from: http://marronebioinnovations.com/products/zequanox/

234 U.S. Geological Survey Upper Midwest Environmental Sciences Center, 2011. Aquatic Invasive Species Control. Available from: http://www.umesc.usgs.gov/aquatic_invasives_team.html

235 Madenjian et al. 2010, *supra* note 119.

236 Johnson, J., 2011, Michigan Dept. of Natural Resources, personal communication, 12 September 2011.

237 Recommendations adapted from Ohio Environmental Protection Agency, *supra* note 146, and Huron River Watershed Council, 2010. Prevent Water Pollution. Available from: http://www.hrwc.org/take-action/homeowners/

NATIONAL WILDLIFE FEDERATION

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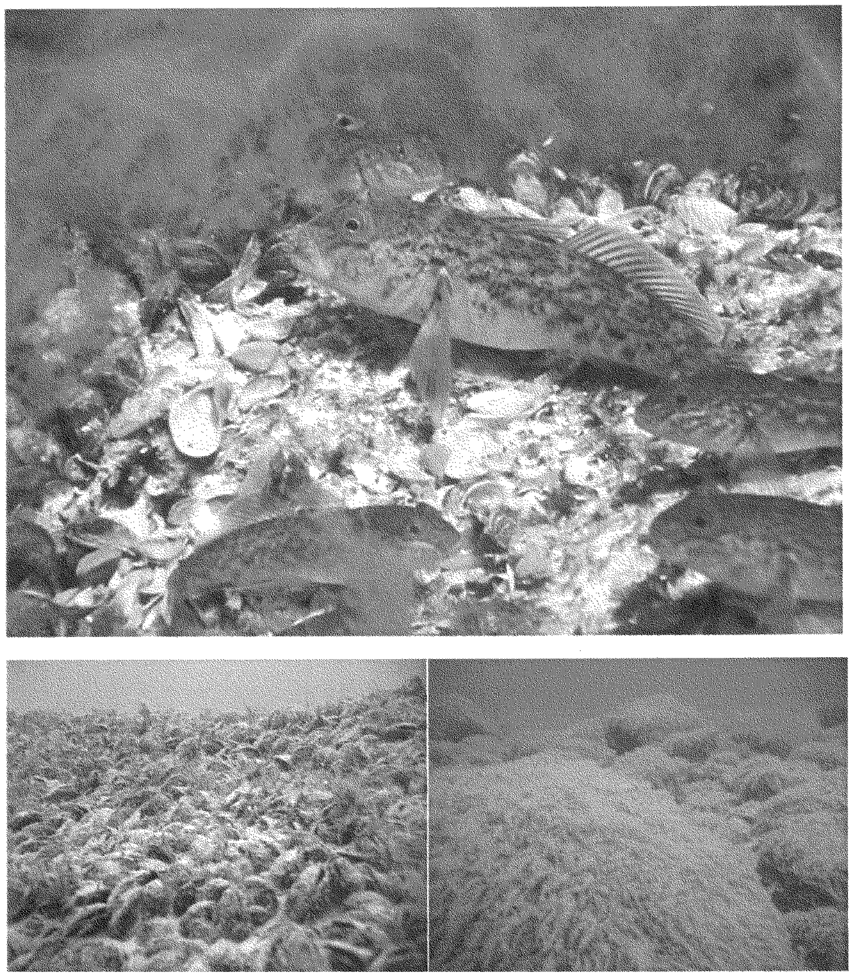
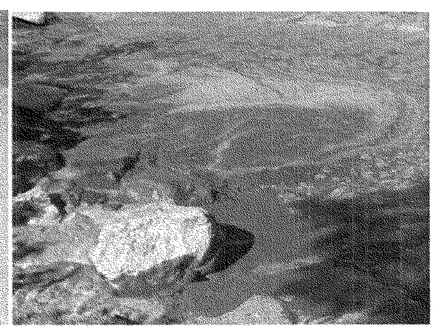
Chladorphora in western Lake Michigan



<u>Exhibit 2- Algal Blooms in the Great Lakes from Above and Below</u>

Algal blooms in Maumee Bay, Lake Erie



Senator CARDIN. Thank you very much for your testimony.
Ms. Chard-McClary.

STATEMENT OF SHELLIE CHARD-McCLARY, DIVISION DIRECTOR, WATER QUALITY DIVISION, OKLAHOMA DEPARTMENT OF ENVIRONMENTAL QUALITY

Ms. MCCLARY. Thank you. My name is Shellie Chard-McClary. I have 19 years experience implementing both Clean Water Act and Safe Drinking Water Act programs in the State of Oklahoma. I also have the added task of also working with our operators through an operator certification training program in my current role as the Water Quality Division Director at DEQ.

I am also on the board of the Association of Clean Water Administrators, who are the voice for the State and interState and territories for implementing Clean Water Act programs. Today I will be delivering testimony on both behalf of my home State of Oklahoma and ACWA.

In its over 40 years of being in existence, the Clean Water Act has allowed us to successfully reduce many sources of pollution in our Nation's waters. One of the areas we are currently addressing is how to reduce the presence in our waters of two pollutants that pose very unique challenges, and those are nitrogen and phosphorus, commonly referred to as nutrients. Today, our nutrient pollution is a leading cause of water quality impairment across the Nation, and it does cause adverse impacts on our drinking water sources, the aesthetics of the water, our recreational uses and on the aquatic life. EPA has a data base that indicates that 21 percent of all water bodies are impaired, the impairments are nutrient related. In Oklahoma we have 10 streams and 22 lakes that are impaired from nutrients.

The data base also shows that 18 percent of all TMDLs that have been completed and approved have been for nutrient related issues. In Oklahoma, we have completed three lake TMDLs for nutrients and we currently have six others in the works.

The most important message I would like for the Committee to come away with today is that the States are doing something. We have a lot of activities, we are addressing these very complicated issues. And I will provide more information later.

First I would like to address why nutrient pollution control is so difficult. Our traditional approach is identifying a single level that a pollutant is too toxic to the environment, and then we set some numeric standard or some narrative standard to keep the pollutant below that level. There is not really a consistent definitive level which we can say that an entire water body or an entire State has too much of a nutrient. Nitrogen and phosphorus are widely variable, they are naturally occurring. They are necessary components to our environment. Just as the amount of calories that a person needs to be healthy depends on height, weight, activity level, the amount of nutrients needed in a water body varies.

The extent to which a nutrient's adverse effects on drinking water, taste and odor problems, we have extreme cases of fish kills, the extent to which it occurs in a water body depends upon a wide range of critical factors that include sunlight, the optimum stream, substrate stream flows, temperatures and the backgroundwater chemistry. These factors are site-specific. Therefore, States have found that nutrient levels that may cause impairment in one stream or one set of conditions may not have the same negative impact.

A single number for nitrogen or phosphorus is not often an accurate indicator of adverse ecological or water quality effects. We have to look at other factors, such as biology and develop with EPA a flexible approach in controlling nutrients. In fact, there is a meeting tomorrow, as you have heard, that State and EPA will be meeting together to hopefully work out some approach.

Another complicating factor in addressing nutrients, we only have the authority over point sources and not those non-point sources. Due to the variation in natural systems, nutrient control and Management call for a wide range of solutions. States are using a wide variety of tools. We are looking at numeric standards, narrative standards, total maximum daily loads, best management practices and looking at other parameters, such as chlorophyll A, looking at sediment and trying other innovative approaches.

We understand that EPA may see it as an opportunity of a one size fits all standard. We don't see that this causes us to have the greatest impacts. W hen we look at what Oklahoma has been able to do through work with our water Resources board, setting both narrative standards and specific numeric standards for certain stream bodies, we have seen successes. We also have seen success through our non-point source program, through our conservation commission, where we have seen 60 to 70 percent reductions in our nutrient pollution.

We have heard a lot about Senator Inhofe's experience, so I won't go into that except to say we know we haven't made it all the way. We have been very successful in making reductions through our point sources and through our non-point source program. But we know we are not there yet, and we are working toward being successful.

Thank you very much for this opportunity to be here before you today and I would be happy to answer any questions that you all may have.

[The prepared statement of Ms. Chard-McClary follows:]

October 4, 2011

Testimony of Shellie Chard-McClary
Water Quality Division, Oklahoma Department of Environmental Quality
and ACWA Board Member

United States Senate

Committee on Environment and Public Works
Subcommittee on Water and Wildlife

Regarding

Nutrient Pollution: An Overview of Nutrient Reduction Approaches – The Essential State Role

Good afternoon, Chairman Cardin, Ranking Member Sessions, and Members of the Subcommittee.

My name is Shellie Chard-McClary. I am the Water Quality Division Director for the Oklahoma DEQ. I have 19 years of experience in implementing Clean Water Act (CWA) and Safe Drinking Water Act (SDWA) programs. An important caveat to ODEQ's CWA authority that is worth noting is that while the ODEQ does not have the responsibility of setting Water Quality Standards (WQS), we do have the daunting task of implementing the WQS through the permitting process. I also serve on the Board of Directors for the Association of Clean Water Administrators (ACWA), the national representative for state, interstate, and territorial officials responsible for Clean Water Act implementation. Today, I am testifying on behalf of both ODEQ and ACWA.

Over its nearly 40 years, the CWA has allowed us to successfully reduce many sources of pollution to our nation's waters. One of the areas we are currently addressing is how to reduce the presence in our waters of two pollutants that present particularly unique challenges – nitrogen and phosphorus (together, "nutrients"). Today, nutrient pollution is a leading cause of water quality impairments across the nation, and causes adverse impacts on drinking water sources, aesthetics, recreational uses, and aquatic life (such as nuisance algae growth, dissolved oxygen reductions, and pH increases). EPA's database indicates that 21 percent of all listed impairments are nutrient related. In Oklahoma, we have 10 stream segments and 22 lakes that are listed as impaired for nutrients. EPA's database also shows that 18 percent of approved Total Maximum Daily Loads (TMDLs) have been developed to address nutrient impairments. Oklahoma has completed three lake TMDLs for nutrients and is working on six others. One important message I would like you to take away today is that states are taking action to address this very complicated and important issue. I will provide additional examples later in my testimony.

First, I would like to address why nutrient pollution control is so difficult. Our traditional approach to controlling a pollutant is to identify the level at which that pollutant is "too toxic" to the environment, and then set water quality-based numeric and/or narrative standards to keep that pollutant below the toxic level. Nutrients are different. There is not a consistent, definitive level at which we can say across an entire state – or even across a water body or watershed – that this level is "too much." Nitrogen and phosphorus are widely variable, naturally occurring, ubiquitous, and are necessary components of healthy ecosystems. Ecosystems can be healthy under a wide variety of nutrient levels. Just as the amount of calories a person needs changes based on the individual's height, weight, metabolism, percent of body fat, exercise habits, etc.; an ecosystem's need for nutrients depends on many factors. The extent to which nutrients' adverse effects (for example, algae growth, pH increases, drinking water taste and odor problems, and in extreme cases, fish kills) occur within a water body depends on a wide range of critical factors such as sunlight, optimal stream substrate, stream flow, temperature and background water chemistry. These factors are site-specific. Therefore, states have found that nutrient levels that may cause impairments in one stream under one set of conditions will not have the same negative impact in a different water body.

A single number for nitrogen or phosphorus is not often an accurate indicator of adverse ecological or water quality effects. We have to look at other factors – like biology – and develop with EPA a flexible approach to controlling nutrients in the environment. In fact, there is a meeting tomorrow between EPA and the states to discuss the approaches states are already using and that integrate biological and ecological assessments to characterize nutrient impairments and develop a viable science-based integrative approach to their control.

Another factor complicating our approaches to addressing nutrient loading to our water bodies is that under the CWA, states only have direct authority over point sources, leaving most of us in a position to only incentivize and encourage nonpoint source reductions (for example, from agriculture). In many watersheds, nonpoint sources may account for a large percentage of nutrient loads. Therefore, expenditures by municipalities and industries aimed at achieving reductions from the end of the pipe may produce little overall gain.

Due to the variation in the natural systems, nutrient control and management calls for a wide range of solutions. States are using a variety of CWA tools to achieve nutrient reductions. These include: nitrogen and phosphorus standards; total maximum daily loads (TMDLs), individual permit limits; wastewater treatment plant optimization; best management practices (BMPs); control of other water quality parameters such as sediment; voluntary nutrient coalitions that involve trading; and other innovative approaches. These diverse approaches require that a variety of nutrient accountability frameworks exist for measuring reductions.

States understand the appeal of a single water quality standard for nitrogen or phosphorus in implementation in order to gain what appears to be a consistent national approach. However, this approach does not acknowledge the real need for a more flexible system, which would allow for nutrient standards to work more effectively in the wide number of applications in which they are used by permitting authorities (for example, NPDES permit effluent limits or the calculation of TMDLs). EPA's Office of Water recently acknowledged our reality in a March 16, 2011 memorandum to its Regional Administrators, stating that, "States need room to innovate and respond to local water quality needs, so a one-size fits all solution to nitrogen and phosphorus pollution is neither desirable nor necessary." States are concerned, however, that this memorandum still establishes the expectation of numeric nitrogen and phosphorus standards.

At this point, I would like to highlight some of the approaches that Oklahoma has been implementing to address nutrient impaired water bodies. The Oklahoma Water Resources Board (OWRB) established narrative criteria for certain water bodies in order to protect them from nutrient loadings that "...impair[ ] any existing or designated beneficial use." Additionally, OWRB established a standard for chlorophyll a, which, although not a nutrient, is a good indicator of the presence of nutrients at levels that may adversely impact water body uses. At the same time, the OWRB established a numeric standard of 0.037 mg/L for phosphorus for the Scenic Rivers. Currently, this standard is being reviewed by a technical advisory panel made up of representatives from Oklahoma, Arkansas, EPA, and the Cherokee Nation. This review exemplifies what can be accomplished when states have the flexibility to set nutrient standards on a site-specific basis.

These three very different standards to address nutrients have resulted in aesthetic improvements to the water bodies that are a part of Eastern Oklahoma's vibrant tourism industry. However, these improvements have come at significant costs to cities and towns in both Oklahoma and Arkansas. The Oklahoma cities of Tahlequah (population 15,000) and Westville (population 1,600) have spent millions of dollars to meet the established criteria.

The Oklahoma Conservation Commission achieved success using a combination of EPA Clean Water Act §319 and state funds to address nonpoint source impaired water bodies through a cooperative program that involves local, state, and federal agencies, as well as local land owners. These partnerships offer a combination of education and voluntary cost-share implementation programs to address nutrient, sediment, and bacteria related impairments. In order to evaluate the success of these programs, there is a monitoring network in place that evaluates water body conditions at over 250 sites.

These efforts have resulted in nutrient loading reductions of between 60% and 70% in Oklahoma's highest priority watersheds. There have been numerous waters taken off our 303(d) list of impaired waters. In fact, in the last two years, Oklahoma has been one of the top five states in the nation for estimated nutrient load reductions due to implementation of the §319 program. Our most recent data suggests significant water quality improvements due to reduced nutrient loading in the top three priority watersheds in the state (Illinois River, Lake Spavinaw, and Grand Lake/Honey Creek). Finally, each year, these programs help hundreds of Oklahoma landowners reduce their impacts and improve their property, helping to ensure that Oklahoma agriculture will continue to play a primary role in feeding the nation and the world. In doing so, the program educates and impacts thousands of people each year about the importance of water resources and what can and is being done to protect them.

I, like most people, enjoy being able to tell others our success stories. However, I feel that it is important that I share with you one of Oklahoma's biggest challenges this year. Late, on June 23, 2011, ODEQ received a call from the Grand River Dam Authority (GRDA). That telephone call was only the beginning of what would turn out to be a very difficult summer and fall. GRDA was calling ODEQ to seek advice on what actions to take based on samples from Grand Lake showing a high presence of toxic Blue Green Algae (BGA). As of October 1, 2011, there were six lakes that were either totally or partially restricted from body contact recreation. The warnings were issued to protect individuals from upper respiratory distress, gastrointestinal disorders and/or skin rashes. The state health department confirmed 17 cases of illnesses from exposure to BGA with two additional still pending.

You may be wondering what this has to do with nutrient levels in water bodies. BGA is routinely present in lakes and rivers in Oklahoma. However, it does not have large blooms or impact recreational activities, or drinking water treatment when it is present in the "normal" levels. However, when the temperature gets very hot and rainfall is limited, the water is likely to become stagnant and when nutrients are present in high concentrations, BGA becomes the dominant algae species. These conditions lead to very large, very rapid BGA growth. Once the BGA completes its life cycle, it releases a toxin, which causes illness from body contact recreation and if consumed in drinking water. With the BGA present in several of the state's larger surface water reservoirs, drinking water systems were faced with additional challenges to filter the BGA without killing it to prevent the release of the toxin.

While we recognize the progress we are making in reducing the impact of nutrients to water bodies; we clearly still have much work to do. The BGA incident that began in late June, and is continuing today, clearly illustrates the impacts that occur to the environment when balance is disrupted.

Because of our experience with BGA this year, we are beginning an internal process that will result in the development of a plan to assist us and public water supply systems, should we find ourselves faced with this situation in the future. These localized events that are driven by many conditions, including those that we cannot control, such as temperature and drought, are another reason why it is so important that states maintain their flexibility in implementing nutrient criteria so that we can take necessary actions to avoid these toxic algal blooms in the future. States need to be able to take into account what happens in a local water body under different conditions in order to adequately protect it. While we have not yet been completely successful in adequately controlling nutrients in our water bodies, we are making progress and will continue to move forward, make adjustments and create more opportunities for success stories.

As ODEQ works with its sister agencies to implement nutrient criteria, we recognize the high cost to reduce the impacts these pollutants have on our water bodies. In a study we conducted, we determined that the estimated costs to reduce nutrient impacts to our sensitive water supply lakes are $29 to $53 million. However, the reduction in the treatment costs required by the drinking water treatment facilities was estimated to be $106 to $600 million. This is a clear example of, "An ounce of prevention is worth a pound of cure."

In conclusion, states share the Administration and Congress's concerns about nutrients and have adopted a variety of approaches, including narrative standards, nitrogen and phosphorus standards, BMPs, watershed plans, etc. In my state, we have developed a variety of approaches since the nutrient issues are dependent on many site-specific issues. State economies, small communities in particular, are already under financial stress and will face additional infrastructure costs if we don't continue to reduce nutrient impairments in water bodies in the most effective environmental and economic manner. In addition, we agree with EPA that it is imperative to prevent additional nutrient impairments from developing, as it is much more economical to prevent impairments than it is to restore a system once it is impaired. We encourage EPA to continue to work with states to develop and implement the most appropriate tools for nutrient reduction and control, and to allow states the flexibility that is crucial to effectively address this important water quality challenge. The right tool is not always a number. The right tool for large urban areas is not always the right tool for small rural areas.

Mr. Chairman, Members of the Subcommittee, I thank you for this opportunity to share ODEQ's and ACWA's thoughts on the importance of the states' role and our on-going efforts in nutrient pollution reduction and control. I will be happy to answer any questions that you may have.

*   *   *   *

OKLAHOMA
DEPARTMENT OF ENVIRONMENTAL QUALITY

Senator Barbara Boxer, Chairman
Committee on Environment and Public Works
United States Senate
Washington, DC 20510-6175

Senator James M. Inhofe, Ranking Member
Committee on Environment and Public Works
United States Senate
Washington, DC 20510-6175

Dear Senators Boxer and Inhofe:

Thank you for the opportunity to appear before the Committee on Environment and Public Works Subcommittee on Water and Wildlife hearing entitled "Nutrient Pollution: An Overview of Nutrient Reduction Approaches." I have received the questions raised by Senators Boxer, Cardin and Inhofe and respectfully submit responses from my perspective as a state regulator for the Oklahoma Department of Environmental Quality, and as a board member of the Association of Clean Water Administrators.

First, in response to the issues raised by Senator Boxer:

"Your testimony calls for a flexible approach led by States. As you also indicated in your testimony, EPA Acting Assistant Administrator, Nancy Stoner, recently issued a memo reaffirming the agency's commitment to partnering with states to reduce nutrient pollution. In this memo, Ms. Stoner stated,

> *'States need room to innovate and respond to local water quality needs, so a one-size fits-all solution to nitrogen and phosphorous pollution is neither desirable nor necessary.'*

At the same time, the EPA IG, NAS and others have recognized the importance of numeric criteria for measuring progress and achieving nutrient reductions. In fact, a nutrient task force co-chaired by ASIWPCA stated that,

> *'Narrative nutrient criteria are widely used but are not easily applied. Adopting numeric nutrient water quality criteria would provide the basis for better assessment of impairments, and for NPDES permit writers to require numeric limits for point source discharges. Numeric criteria could also be used as a tool to set nutrient capping levels for point and nonpoint sources.'*

As this report suggests, isn't it correct that numeric limits are an important tool to help reduce nutrient pollution?

Also, isn't it true that numeric limits can be used in combination with other tools, enabling states to establish a baseline to measure progress while allowing for flexibility in achieving nutrient reductions?"

There is no question that numeric nutrient criteria are important and play a key role in addressing nutrient pollution. However, they are problematic when a "one size fits all approach" is applied. It is important to use numeric criteria where appropriate and partner it with other tools such as narrative criteria. Oklahoma has successfully combined the two approaches in the Illinois River Watershed in Northeastern Oklahoma. In this area, a numeric criterion has been established for phosphorus (P) and is applied to point source dischargers, including municipalities and industries in both Oklahoma and Arkansas. In addition, there is a narrative criterion that is applied to the non-point sources in the area. Based on this integrated approach there have been documented improvements in this important Scenic River. However, these improvements have come at a significant cost to the point source dischargers. The high cost to comply with discharge limits based on the numeric criterion is due to the fundamental difference established in the Clean Water Act for point sources (regulatory) and non-point sources (voluntary). This disparity is even more extreme when the amount of nutrient contribution between the point sources and non-point sources is evaluated. It is only the point source dischargers, industries and municipalities, which must comply with the standard; while non-point sources are encouraged to take voluntary steps.

Another important tool that states are using is partnerships that are formed with various other government entities. In the case of the Oklahoma phosphorus criterion, there is a work group consisting of multiple state agencies from two states, tribal governments and EPA. This group has diligently worked to evaluate the appropriateness of the P standard and to make recommendations to the Oklahoma Water Resources Board at an upcoming meeting. The difficulty comes when determining how to best implement the established numeric standard since not all nutrient contributors are bound to comply. It is difficult to convince many people that the difference between a 0.1 mg/L P limit and a 1.0 mg/L P limit is worth the high cost of treatment. It is, however, easier to convince the public that large algal blooms creating pea green water covered with "slime" in a recreational water body is bad. A single number does not improve the water quality, but works with other methods to be successful in preserving and returning beneficial uses to the water body.

There are multiple ways to establish a baseline. While setting a specific numeric standard is one method that can be evaluated by testing a specific parameter and comparing results to a predetermined number, it is not always the best indicator. For example, at the same level of nutrients the rate of algal growth is significantly different when temperatures are higher and when water in a lake becomes stagnant. Therefore, a specific numeric standard for a water body may be protective only under certain weather conditions. Another key factor in evaluating nutrients is the type of water body. There are significant differences in addressing nutrient impacts in a flowing river versus an intermittent stream versus a large lake with many streams flowing in, varying depths, etc. A river with a large and consistent flow many not show impacts of the presence of nutrients until the concentration is quite high. However, small rivers with continuous flow will likely show impacts at lower concentrations. In the case of lakes, rainfall and accumulation of nutrients over a long period of time, as well as temperature, will dictate the impact on the lake of the concentration and the mass loading of the nutrients.

Second, in response to the specific issues raised by Senator Cardin:

"Can numeric limits on nutrients be used in combination with other tools, enabling states to establish a baseline to measure progress while allowing for flexibility in achieving nutrient reductions?"

As discussed above in response to Senator Boxer's question, nutrient numeric limits are one tool that is available. It must not be viewed as the only tool or as a preferred tool. It is important to incorporate other tools like narrative standards, conservation programs, etc. Using numeric standards as the baseline can be problematic. As stated above, numeric nutrient criteria lead to a permit limit that point source discharges must attain while non-point source discharges are encouraged to take some action to reduce nutrient runoff into the water body. The single number may or may not impact the amount of algae growing in a given stream segment since other factors, such as temperature change, can cause greater growth.

Nutrients are very different from other pollution sources in that they have varied impacts on a water body based on other conditions outside human control such as temperature and rainfall events. The same amount of nutrients in a stagnant water body with prolonged temperature in excess of 100^0F will cause higher rates of certain types of algae. If the baseline is a single number, it will only be protective under consistent weather conditions. However, narrative criteria can be applied regardless of changing conditions. Multiple tools are available and should be considered whenever making decisions that impact not only the environment but also local industries and cities.

"Do you think a nutrient-trading program would be an effective way to manage and reduce nutrient pollution? Why or why not?"

Nutrient trading programs are another tool available to address nutrient loadings in water bodies. As with most options to solve problems, the likelihood of success depends on many factors; three of which are discussed here. First, there must be an acknowledgement of the need for a trading program and a long term commitment by the multiple sectors impacting the water body. Without multiple parties invested there is no market to implement the tradeoffs. Second, a system must be developed to document the trade arrangement. If the benefit cannot be documented and realized, the public and EPA will not recognize the improvement that has been made in that water body. Finally, a "mind set" change is necessary. Pollutant trading is a relatively new idea compared to the 40 year history of the Clean Water Act. Regulators, environmental activists, point source dischargers and non-point source contributors must work together to determine the best approach to spend limited dollars that will reduce the overall contribution of a pollutant to a water body rather than evaluating each contributing piece individually.

There are approximately 15 states that either have implemented trading programs or that have trading programs under development. Maryland, Pennsylvania, Virginia and West Virginia have introduced nutrient trading programs to address nutrient pollution in the Chesapeake Bay. All four allow the trading of nitrogen and phosphorus, while all but Virginia also allow for sediment trading. Other examples of trading programs include Connecticut's Nitrogen Exchange Credit Program for Long Island Sound and Denver, Colorado's Cherry Creek Reservoir Watershed Trading Program. These programs were developed to solve a specific pollutant problem using site specific criteria. Additionally, there was substantial buy-in from impacted entities. Without that buy-in, the trading programs would have no chance for successfully reducing pollutants into the water body.

Finally, in response to the specific issues raised by Senator Inhofe:

Why is a single number for nitrogen or phosphorus usually not an accurate indicator of adverse ecological or water quality effects? Why do you believe EPA is continuing to *press states to adopt a single, one-size-fits-all number? Is using a single-number approach scientifically sound?*

Nitrogen and phosphorus are vital nutrients to all living organisms. However, in excess quantities, nutrients cause impairments to water bodies. Stating that all water bodies should have a single nitrogen or phosphorus criterion would be the equivalent of a dietician stating that all people should eat twelve ounces of protein every day. For some people that is an excessive amount of protein and for others that is an inadequate amount of protein. They are all people, but their size, metabolism, muscle content, etc. dictate a different level of protein that is needed to be healthy. Water bodies are not different. The organisms living in that water body must have at least a minimum amount of nutrients to survive, but excessive qualities of nutrients cause greater growth of certain organisms, such as algae, that can result in a negative impact on the water body. Finding an acceptable balance is the key.

EPA is struggling to demonstrate the success of CWA programs due to the number of third party lawsuits that are filed, the number of inquiries from media and other entities, their limited resources, and the natural variations that occur throughout a country consisting of 50 states, all with very diverse geography, climate, natural resources, industries, farming practices, residential landscape practices, etc. In order for EPA to acknowledge the concerns expressed by some that EPA is not taking appropriate actions to adequately implement the CWA, a standardized process where all states are treated identically, i.e., nutrient numeric criteria, was the result. While EPA has good intentions, this approach does not adequately consider all significant factors.

Climate and geography play a key role in nutrient management. A water body in a hot climate is likely to experience greater biological growth than a water body in a cold climate with the same nutrient content. While it appears obvious that some of these differences can be addressed by allowing states to set state specific criteria, there are many instances, particularly in the larger geographic states, and states with wildly varying temperature swings over the course of a year, where the same water body may experience prolonged periods of both high and low temperatures. Examples of the impact of temperature in water bodies with consistent nutrient levels would be Grand Lake and Lake Tenkiller in Oklahoma. This summer, when temperatures were in excess of 100^0F for a prolonged period of time (more than 100 days by summer's end), the population of blue-green algae exploded and caused illness in humans and animals. However, in the months prior to and following the extreme heat, the population returned to a "normal" level. If a single number had been established for nitrogen or phosphorus, it could have been established at a level that showed no impact during cooler weather but was detrimental in warmer weather; or conversely, if the criteria had been established to be protective in warmer weather it may have been cost prohibitive to implement.

The costs associated with addressing nutrient pollution is borne almost exclusively by point source dischargers, i.e., municipalities and industries. The voluntary nature in which non-point source programs are implemented make it unlikely that individuals/corporations will expend the resources necessary to make a significant contribution to the reduction of nutrients in water bodies. The CWA Section 319 program allows funding for certain projects that demonstrate and implement cost effective solutions to reduce the runoff from eligible areas.

Another area that is extremely difficult to address is the habit of the public regarding fertilizing their lawns. There are no current regulations that state how much fertilizer each individual is allowed to apply to their privately owned property. There is no requirement or simple method that allows individuals to sample the soil and get a quick and easy answer to how much or what kind of fertilizer is needed by the lawn. Over fertilization results in additional nitrogen and phosphorus running off the property, through storm drains, and into nearby water bodies. Currently, this creates an almost impossible situation for point sources to reduce their contribution enough to offset what is occurring through "unregulated" sources.

On the surface, it appears that if one consistent number or process is established, all states can be compared to each other in an "apples to apples" manner. This leads to the ability for EPA to provide "consistent and comprehensive oversight" of state programs. However, the reality is not an appropriate measure of whether or not a water body is healthy, but rather a predetermined number that may or may not be applicable. States have demonstrated that there are multiple approaches to address nutrients. EPA appears to be listening to the states and appears willing to allow a flexible approach, rather than a scientifically developed standard based on only one set of criteria. Unlike with metals or other pollutants, it is necessary to consider additional environmental conditions to appropriately develop a numeric standard.

EPA's approach of allowing states to establish standards on a stream segment or water body specific basis is appropriate and scientifically sound. However, problems arise when the approach extends beyond those small segments, and when the numeric standard is the only approach that is actively applied.

EPA "strongly believes that states should lead the effort" to reduce nutrient pollution, and EPA is "committed to finding collaborative solutions" and building "partnerships with states and collaboration with stakeholders." From your vantage point, and judging by EPA's actions, is EPA being "collaborative" and willing to let the states "lead the effort" in dealing with nutrient pollution? Why or why not?

There is no question that at times EPA has not been collaborative and willing to let the states lead the effort in addressing nutrient pollution. The most obvious example is the development and promulgation of numeric nutrient criteria in Florida. (See testimony provided by Richard Budell, Florida Department of Agriculture and Consumer Services) However, recent developments indicate that EPA is willing to work more closely with Florida and has indicated that it will likely approve the criteria that Florida has proposed, which calls for flexibility and a "biological confirmation approach."

From a broader perspective, EPA is currently making an effort to meet with states and discuss options, approaches, guidance, etc. Time will tell if the end result is a collaborative process or simply a series of meetings for the sake of claiming to have sought out state input.

Was Oklahoma consulted prior to the issuance of EPA's March 16, 2011, nutrients "framework" memo? How could EPA improve the "framework" memo to ensure that they are empowering states to tackle these issues in a scientifically sound way?

Oklahoma works very closely with the Association of Clean Water Administrators (ACWA), previously known as ASIWPCA. In fact, several Oklahoma environmental agency staff hold task force/committee and Board positions. This allows Oklahoma to participate on a wide range of issues that are important to the state. Oklahoma was part of the team of states that worked with ACWA and EPA on this critical issue. In fact, Oklahoma had a representative present at the meeting on October 5, 2011 that was referenced by several individuals during the hearing.

ACWA members generally had a positive response, as EPA called for flexibility and the need to allow states the ability to innovate. In the memo, EPA recognized that a one-size-fits-all solution to nitrogen and phosphorus pollution is not the right way to go.

However, while our members agreed with EPA on much of the memo's content, they did feel that one of EPA's recommended elements of a state framework, which calls for the development of numeric nitrogen or phosphorus criteria for at least one class of waters within the state within three to five years, undermined the earlier call for flexibility. At the same time, however, perhaps this is counterbalanced by EPA's actions in Florida, which indicate flexibility. For example, in EPA's letter sent in response to Florida's November 2, 2011 release of the proposed rule, EPA states that it is prepared to support a "biological confirmation approach" to determining stream nutrient health. This approach is a combination of numeric nutrient criteria and bio-criteria. In order for the "framework" memo to be helpful to the states, EPA must abide by the memo to allow the stated desire for states to have the flexibility to adequately and appropriately address nutrients. Additionally, EPA must recognize that when flexibility and site specific criteria are being applied, there may or may not be a nitrogen or phosphorus numeric criterion in a three to five year time frame.

EPA must also continue to embrace alternative methods in evaluating criteria to determine if an already established criterion is appropriate or should be modified. A specific example in Oklahoma: there is a Technical Advisory Group that is headed by staff at the Oklahoma Water Resources Board and includes staff from three other Oklahoma state agencies, two agencies from Arkansas, a Tribal representative and an EPA Region VI representative. This group has reviewed scientific information and plans to make a recommendation soon to the Board that establishes Water Quality Standards in Oklahoma. This type of collaborative effort will be instrumental to developing and implementing nutrient standards, whether narrative or numeric, in the future.

How important are State Revolving funds to Oklahoma in terms of reducing nutrient pollution? What about other EPA funding, like §319 grants?

Both of these funding sources are vitally important to the ability to minimize the human impact on the environment. The Clean Water Act State Revolving Fund is a significant source of funding for municipalities to expand or upgrade existing wastewater treatment facilities, or to construct new wastewater treatment facilities in order to comply with the ever increasing federal regulations including those related to nutrients. Some states, like Oklahoma, have taken advantage of the federal funding each year and leveraged funds to create $7 (or more) for every $1 provided in federal funding from EPA. The low interest rates, principle forgiveness, and subsidization make it an attractive source of funding. However, in order to access the funding, the municipalities must be able to demonstrate an ability to repay the loan. Without this key funding source, the municipalities would be left to secure higher interest bank loans, sell their own bonds on the bond market (if they have the capacity), fund all improvements through sales tax or utility rate hikes, or do nothing and provide inadequate treatment.

The Section 319 funding is critical to funding education and conservation practices, and demonstration projects that dramatically reduce the amount of nutrient runoff into water bodies. The 319 program in Oklahoma has been able to document a 60%-70% nutrient load reduction in several of the state's highest priority watersheds. Additionally, the education programs work with landowners to help them reduce their impact on the environment while continuing to play a vital role in the nation's food supply. Without adequate funding, there will be fewer success stories and state efforts focused on non-point source contributors will become much more limited.

EPA has published on its website the success stories related to the 319 program. (http://water.epa.gov/polwaste/nps/success319)

Why is using a "consensus" approach, where you have buy-in from the regulated community, important in developing standards and an overall water quality strategy for addressing nutrients?

A consensus approach is/will be vital to any successful strategy to address nutrients in water bodies. Only when individuals, municipalities and commercial facilities recognize and understand the role they play in elevating the level of nutrients in a water body do they fully understand the need for them to take action to minimize the nutrient runoff. Additionally, when educational organizations (schools, universities, Boy Scouts, etc.) understand the causes and effects, they can work to encourage preventative measures at earlier stages. Ensuring that there is an understanding by the general public is also vital in order to be successful. If there is not "buy in" from all the various interested parties, they will work against each other. For example, if the only focus is on point sources, large amounts of money could be spent for only minimal improvement to the water body. Then, when civic or other citizens groups see the lack of progress, lawsuits could be filed to further reduce the impact of point sources, which may already have reduced their contribution to a level at which additional treatment is not available financially or at all. Under a consensus approach, the point sources would do their part, the non-point sources would reduce their contribution, and home owners would do their part to reduce over fertilization and runoff, which would likely result in an improvement to the water body.

Finally, it is important for EPA and the state agencies to reach a consensus on the appropriate approach for a water body. If EPA is not on board with the actions of the state, there could be duplication of efforts where an entity has different state and federal criteria to meet, wasted resources, etc.

Ultimately, when all groups understand the process that will be followed, there can be a "grassroots" effort to make improvements to impaired water bodies and prevent others from becoming impaired. More can be accomplished when all sides are working together rather than in opposition.

If nutrient standards are based on environmental response parameters, is it possible to develop permit limits for nitrogen and phosphorus? If a state relies solely on environmental response parameters to determine impairment, does that mean that action will not be taken on a waterbody until impairment has already occurred?

It would be "possible" to develop a permit limit based on environmental response parameters, although Oklahoma has never done so and is unaware of a State that has done so. It would be a very data-intensive exercise, requiring extensive site-specific data to show the relationship between nutrient levels and algae growth and a mechanism to determine when the algal growth would be considered "excessive". These kinds of data don't usually exist without a specific monitoring program. However, if the data was available, a numeric target for nitrogen and/or phosphorus could be derived and a permit limit could then be calculated.

Due to the complexity of the issue and the limited resources that states have, generally, actions have not been taken to impose nutrient reductions unless impairment has been documented. However, that would not necessarily have to be the case. If there was a narrative criterion and adequate water body data to determine response thresholds, and a procedure to translate those nutrient levels into permit limits, it would become just like any other water quality standard. A reasonable potential analysis could be performed and used to determine if a permit limit was needed prospectively to avoid exceeding the determined threshold.

Is there anything else you would like to add for the record?

Nutrient impairments of water bodies in the United States are a problem. States recognize this problem and are working to address nutrients in a logical, economical, and appropriate site-specific manner. Municipalities, industries, EPA, states, citizens groups, educators, scientists, etc. must work together to develop and implement appropriate solutions to this important environmental challenge.

One current effort that is underway, ACWA is conducting a survey to gather information on alternative approaches to nutrient reduction, including trading programs. The study has a planned release of early next year. This is another tool that states will be able to use in order to address nutrients in our nation's water bodies.

Thank you for the opportunity to participate in the dialogue of this important issue. If you have any questions or need additional information, please contact me at (405) 702-8157 or by email at Shellie.Chard-McClary@deq.ok.gov .

Sincerely,

Shellie Chard-McClary

Shellie Chard-McClary
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Oklahoma Department of Environmental Quality
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Senator CARDIN. Before Senator Inhofe leaves, I am sure that you had made special note of that one lake, and you will do some work there.

Ms. CHARD-MCCLARY. We have done quite a bit of monitoring work. We have over 250 monitoring sites. We are working with about seven lakes that as of today are still showing impairment. But it is an ongoing process with our State and local partners. We also have worked very closely with several of our Federal partners.

But we hope to maintain a partnership.

Senator CARDIN. Thank you.

Mr. Maravell.

STATEMENT OF NICK MARAVELL, MARYLAND CROP, LIVESTOCK AND VEGETABLE FARMER

Mr. MARAVELL. Chairman Cardin, Ranking Member Sessions, members of the Subcommittee, I am Nick Maravell, an organic farmer for the past 30 years.

We farm 170 acres in Montgomery and Frederick Counties, Maryland, producing livestock, hay, grain and vegetables. Let me give a partial list of our practices relative to nutrient management. Recycling of on-farm nutrients, fixing nitrogen and carbon from the air into the soil, lengthy crop rotations, multiple species plantings, including plenty of legumes, winter and summer cover crops, intensive rotational livestock grazing, no-till planting into standing crops, stubble and perennial crops, slow release of nutrients, very minimal use of highly water-soluble nutrients and minimum use of off-farm fertility inputs.

We have been able to weather good years and bad due to our improving soil quality. We have also led to a better water quality through more efficient nutrient use and better nutrient holding capacity. We manage our manure to conserve its nutrients. We raise all of our feed for our livestock. Our beef never leave pasture. Our poultry are moved across our pastures. Thus, we manage our livestock so that manure does not accumulate in once place, has a chance to decompose quickly and surface runoff is readily absorbed into soil covered with vegetation.

We add value to our products by making them organic and grass-fed, by selling them directly to the final user, and by on-farm processing of our poultry, poultry feed and seed stock. Our minimal impact on the environment is a major selling point with our customers. Our sales growth averages 10 to 20 percent each year, on par with the growth of the $30 billion nationwide organic industry. Our farming system lacks characteristics often associated with increased risks of nutrient pollution.

We are not a confined animal feeding operation centralizing the accumulation of manure. We do not specialize in primarily one type of product. We do not rely primarily upon off-farm water soluble fertilizers to supply our nutrients. We do not have very large fields with short, 2-year rotations of monocultures. We do not produce for a commodity or export market, we do not lose the identity of our product as it is marketed.

American agriculture is very varied, and that diversity is a tremendous strength that should be preserved. Because there is no one model that should apply to all farms, our national policy and program should have the flexibility to accommodate our legitimate differences. I call this the multiple models approach. For example, Congress' Chesapeake Bay Watershed Initiative of 2008 is tailored to provide regional nutrient pollution reduction. It needs to be expanded to assure farmers of the help they need to meet new mandates.

States need flexibility to work with farmers, particularly more latitude to allocate technical assistance funds to have maximum impact on reducing nutrient pollution.

Finally, I will comment on some of the approaches that have been most helpful to me. On-farm research and onsite technical assistance have been the most successful approach to improving our fertility decisions. Market forces that increase the farmer's bottom line for providing ecological services are very effective. Allowing for some identity preservation of farm products provides the ultimate and direct accountability between agriculture and our local and regional environmental preservation efforts.

Assistance to plant cover crops is an excellent approach to recycling nutrients. States could provide more flexibility in such areas planting multiple species, using innovative species, setting earlier and later planting dates, and exploring summer covers. Assistance to farmers who are responsibly managing their soil and nutrients but who want to make further improvements is an excellent approach, such as the Conservation Stewardship program. Such programs must be sure to cover various farm models and levels of accomplishment.

For farms that do not accumulate large amounts of nutrients, particularly manure, the State should allow filing a new nutrient management plan once every 5 years with annual updates, rather than once every 3 years. I applaud the efforts of the Subcommittee to work with family farmers to help them remain profitable while increasing their ability to effectively manage their nutrients.

[The prepared statement of Mr. Maravell follows:]

Statement of

Nick Maravell

Maryland Organic Crop, Livestock and Vegetable Farmer

On

Nutrient Pollution: An Overview of Nutrient Reduction Approaches

Before the US Senate Committee on
Environmental and Public Works

Subcommittee on Water and Wildlife

October 4, 2011

Senator Cardin, Senator Sessions and Members of the Subcommittee, I am Nick Maravell, an organic crop, livestock and vegetable farmer for the past 30 years.

I own and operate Nick's Organic Farm, located in Montgomery and Frederick Counties, Maryland. We have 170 acres in production. I consider us a small family farm.

We operate a diversified and integrated farm, raising several types of crops and animals together. As an ecologically based operation, we rely on crop and animal diversity, lengthy crop rotations and rotational grazing. We strive to manage our nutrients with minimum risk of polluting our waters.

Our farm is continually evolving—a work in progress-- as we look for ways to improve our practices. We currently conduct on-farm research in conjunction with USDA's Beltsville Agricultural Research Center, and have previously cooperated with the University of Maryland and the Maryland Department of Agriculture. We have been able to weather good years and bad due to our improving soil quality—which has also lead to better water quality through more efficient nutrient use and better nutrient holding capacity.

With minimal off-farm fertility inputs, we raise grass fed Angus beef, pastured chickens and turkeys, and free range eggs. We sell various types of mixed hays. We produce field corn, soybeans, and barley. We grind our grains and sell organic poultry feed. We grow fresh vegetable soybeans in addition to producing organic, GMO-free seed for food grade corn and soybeans.

Equally important to our production is our marketing strategy; it reflects our product diversity, our small size and our customer's desire for local and sustainable production.

We must add value on-farm to be economically viable. We do this by making our products organic and grassfed, by selling about 90% directly to the final user, and by on-farm processing. We process our own poultry, pack our eggs and vegetable soybeans, condition our seed, and grind our grains into poultry feed.

On average, our sales growth is 10-20% each year, on par with the general growth rate of the $30 billion nationwide organic industry. Our markets are local and regional, and our minimal impact on the environment is very important to us and our customers and a major selling point for our products.

To understand how we manage our nutrients and guard against nutrient pollution, I will briefly describe our farming philosophy and specific practices, and comment on my experience with existing programs.

We view half of our farm as living above the ground and the other half as living in the soil. We begin constructing our farming system around the long term sustainability of the soil.

For example, when we took over the corn-soybean fields at the Frederick farm, a three foot wide by one and a half foot deep erosion gulley cut through the center of the farm, having formed that season. That fall we filled it in by disking. Then we began our rotations, smaller field sizes, and contour farming. Erosion has never returned to the farm, despite the fact that all of our soils are classified as highly erodable.

We are trying to produce a soil with rich biological activity, good tilth and soil structure, good water holding capacity, good aeration, and the appropriate amount of available plant nutrients. In general, adding organic matter to the soil and minimizing tillage are good ways to achieve these characteristics.

Our soil building program is based on crop rotations, cover crops, animal rotations, and minimal off farm inputs. We have an 8-12 year rotation that includes alfalfa/grass hay, pasture, corn, soybeans, and barley. Our rotations are interspersed with cool weather cover crops of rye grain or barley with hairy vetch, and warm weather crops of sorghum and sorghum/sudangrass and cowpeas. Often these crops are planted no-till into previous crops or directly into perennial hay or pasture.

Except for our corn and beans, we rely on multiple species plantings to take advantage of each species unique strengths in foraging for nutrients which ultimately can be recycled from that crop's organic residue and made available for the next crop to use. Multiple species plantings generally create more total biomass by occupying different ecological niches or layers in the growing area, thereby providing good ground cover for erosion control and increasing organic matter returned to the soil.

Our small field sizes of 7-15 acres allow us to tailor our fertility practices to the lay of the land and its specific nutrient needs. We add high calcium agricultural lime every 3-7 years depending on need. We add potassium sulfate and soft colloidal rock phosphate less frequently, as needed in specific fields. Once or twice every 8-12 years, a field may be amended with 2 tons per acre of off-farm poultry litter ahead of planting corn. With the exception of the poultry litter, all these sources of off farm nutrients are slow release, not highly water soluble, and pose very little risk of polluting our waters. Soon we hope to add nutrients through on-farm composting made from local food scraps, off-farm poultry litter, and wood chips.

Our nitrogen is supplied both through growing and incorporating legumes (alfalfa, vetch, clover, soybeans, field peas, cowpeas), incorporating organic plant residues from previous crops, and roots sloughed off after each hay cuttings—usually five times each season. Other sources of nitrogen are derived from earthworms and other macro and micro biological activity in the soil, and manure from rotational grazing of beef and poultry.

Of our nitrogen sources, the animal manure has the most potential for nutrient pollution. We try to manage our livestock so that manure does not accumulate in one place, has a chance to decompose quickly, and surface run off is readily absorbed into soil covered with vegetation.

We have no streams running through our farms. We have only 80 head of cattle and a few hundred chickens on about 150 acres of cultivated land.

We also use grassed waterways and still farm our fields on the contour. In addition we have grassed buffer zones (25-50 feet wide) to separate our farm from neighboring non-organic farmland.

To prevent manure build up, feed and water is constantly moved. Mobile pens without floors move the poultry across the pastures. Hay for our beef is unrolled on the ground in constantly changing locations or fed from feeder wagons constantly moved. In non-freezing weather, our watering system is mobile. Our beef are never fed grain and are never brought inside (except for a sick animal), so we do not accumulate manure piles.

Our farming system lacks certain characteristics, prevalent on many farms today, some of which if not carefully managed, can increase the risk of nutrient pollution:

- We are not a highly concentrated confined animal feeding operation centralizing the accumulation of manure on a land base that cannot produce enough feed for all of its livestock.

- We do not specialize in primarily one type of production, such as livestock, cash grains or fiber, forages, vegetables, or perennials.

- We do not rely primarily on off-farm water soluble fertilizers to supply nutrients to our plants.

- We do not have very large fields with short 2 year rotations of monocultures, such as corn-wheat-beans.
- We do not produce for a commodity or export market.
- We do not lose the identity of our product as it is marketed.

Let me emphasize that American agriculture is very varied, and that diversity is a tremendous strength that should be preserved. Because there is no one model that should apply to all farms, our national policy and programs should have the flexibility to accommodate our legitimate differences. I like to call this the multiple models approach.

To the extent that farming systems similar to ours are desirable for reducing nutrient pollution, our Federal programs should be examined to determine if they are structured properly to provide support and incentives for other farms to adopt these practices. From my experience, some restructuring may be needed. Let me explain.

Because our farm is different in many ways from the majority of America's farms, we often do not easily meet the eligibility criteria for the programs created to reduce nutrient pollution and encourage conservation. This is both a problem and an opportunity. The problem is most existing programs do not provide a strong incentive to adopt ***comprehensive*** approaches that inherently prevent nutrient pollution—most programs go after specific practices only, not complete systems.

The opportunity is to promote new programs tailored to the regional nutrient reduction needs of our nation's farms. For example, in 2008 Congress created the Chesapeake Bay Watershed Initiative to help farmers address nutrient runoff. It is so important to farmers that Congress continue and expand this program. I talk with many other farmers who feel the responsibility and pressure from their states to address these nutrient problems for the Bay, but they are very anxious about being able to afford new mandates and uncertain about the availability of future funding. These farmers need help to accomplish the states' requirements for reducing nutrient pollution. At the same time the states need flexibility to work with their farmers to achieve these nutrient pollution reduction goals. One area in particular where the states could use more flexibility is in the allocation of technical assistance funds to the areas and through the programs that will have maximum impact on reducing nutrient pollution. Right now these technical assistance funds can only be used through EQIP, the Environmental Quality Incentives Program.

Finally, I want to comment on what nutrient pollution reduction approaches have been most helpful to me and what approaches could use improvement.

- On-farm research in collaboration with research personnel has always proved to be the most successful approach to improving our fertility decisions without increasing nutrient pollution. The on-farm research can be made most effective when dissemination of results to other farms is combined with onsite technical assistance from the research, extension, and conservation community. In these times of budget constraint, I think the argument can be made that it is far less expensive to prevent nutrient pollution than remediate its ill effects.

- I have found that market forces are an extremely effective incentive in increasing the farmer's economic bottom line for providing ecological services to his locality or region. Bringing consumers and farmers together or allowing for some identity preservation of farm products provide the ultimate and direct accountability between agriculture and our local and regional environmental preservation efforts. Our State Department of Agriculture has advanced such efforts as farmer's markets, Maryland's Best Label, defining "local production," and administering the Organic Certification Program and label.

- Providing assistance to plant cover crops is an excellent approach to recycling nutrients. However, states could explicitly provide more flexibility in such areas as: planting multiple species, using new innovative species, setting earlier and later planting dates, exploring summer covers. Maryland has made great strides in some of these areas, but more could be done.

- Providing assistance to farmers who are responsibly managing their soil and nutrients but who want to make further improvements is an excellent approach. The Conservation Stewardship Program (CSP) attempts to move in this direction, but when I applied I found that from the national level the program had built in biases that did not fit my farming model and that of many other organic and sustainable farmers. The CSP strongly favors no-till planting and does not easily accommodate operations that rotate animals and annual crops over the same ground. While our state scored our farm in the highest possible tier and awarded us a grant, or grant terms restrict our pasturing and crop options.

- Because our farming system does not accumulate large amounts of nutrients that can easily enter our water ways, filing our Nutrient Management Plan once every three years with annual updates has not resulted in our changing any of our practices. The State should provide the flexibility to require some operations, in the absence of major changes, to file a new plan once every five years with annual updates. This change could save time, money and staff resources, which could be redirected to onsite technical assistance.

- Other than through the cover crop program, our farm has never received assistance under EQIP, the Environmental Quality Incentives Program. Perhaps that is our fault, but somehow the criteria just never seem to fit well with our circumstances. As one district conservationist said after we walked the entire farm together, "There are no environmental benefits to be derived from this farm." He enlightened me by saying our farm did not have any recognizable environmental problems. I am encouraged by some recent EQIP initiatives that are designed to provide incentives to move toward environmentally sustainable practices without first having to demonstrate the prevalence of less sustainable practices.

I applaud the effort of this subcommittee to work with family farmers to help them remain profitable while increasing their ability to effectively manage their nutrients.

Senator CARDIN. Thank you very much for your testimony.
Mr. Hawkins.

STATEMENT OF GEORGE S. HAWKINS, GENERAL MANAGER, DISTRICT OF COLUMBIA WATER AND SEWER AUTHORITY

Mr. HAWKINS. Subcommittee Chair Cardin, Ranking Member Sessions, my name is George Hawkins. I am the General Manager of D.C. Water. I am delighted to be here today.

I want to point out first I am delighted to have D.C. water right here at the table. We have been trying to persuade the House, on the other side, to give up water bottles, to use our water. It is a good way to save money and we deliver you clean, fresh water every day.

I am delighted to be here, Senator Cardin. I don't know if you remember the very first event I held in D.C. 5 years ago, when I came to run the D.C. Department of Environment, was a clean-up grant you helped get for Marvin Gaye Park, for one of the tributaries of the Anacostia River. Actually, it was before my first day, coming here back to D.C. Delighted to see you again.

I want to say three things today. One, tell you a little bit about D.C. Water; two, tell you about the three projects we are undertaking to reduce nutrients that at scale dwarf anything you have heard; and three, tell you some of the lessons we have learned.

First, about D.C. Water. D.C. Water takes water from the Potomac, it is actually a Federal agency that cleans it, where 75 percent of the water from that agency comes to us, almost all of their funding is from D.C. Water ratepayers. We deliver that water to you, including what is right here. Once that water is used, it comes back down the drain and back to us, we cleanse it and it goes back to the Potomac. It is a true recycling system of massive scale. Most do not know the scale of what authorities like mine do at every municipality around the Country.

To give you a sense, tomorrow morning I will present to our board a proposed budget for 2013. Our operating budget is $456.8 million for one fiscal year. Our capital budget is $606 million for one fiscal year. That is $1.1 billion for Fiscal Year 2013 for Washington, DC. metropolitan area.

Many of the people in this room are ratepayers of D.C. Water. You have paid a 40 percent rate increase over the last 3 years, projected 10 percent more for these costs. What are we doing with this money?

The first project is called the Long Term Control Plan. We call it Clean Rivers. We will be building tunnels as big as this room, from here to the ceiling, 100 feet below your feet to capture overflow that otherwise would go to the Anacostia, to Rock Creek and the Potomac. Over 3 billion gallons will be captured in most calendar years, eliminating overflows from 82 in the average year to 2. The cost of that project is $2.6 billion, paid for primarily by D.C. ratepayers.

The second project is to enhance nitrogen removal. That is the next stage for the Chesapeake Bay. The only jurisdiction of the six plus the District of Columbia that met the 2000 and 2010 goals for the Chesapeake Bay was the District of Columbia. D.C. met it because D.C. Water met its goals, because we are literally the only big discharger in the District of Columbia, and we are the largest single discharger in the entire Chesapeake Bay.

To give you a sense of costs, between 1985 and 2000, we reduced 5.6 million pounds of nitrogen at the cost of $16 million. From 2000 to 2010, we reduced an additional 3.5 million pounds of nitrogen for $100 million. From 2010 to 2015, we will reduce another 600,000 pounds of nitrogen for $900 million, the project we are doing today. So from about 6 million pounds for $20 million, it is 600,000 pounds for $900 million. It costs us 45 times more at the margin to reduce nutrients from wastewater treatment today than it did 40 years ago, because of the success we have engendered. But we are at the cost margin.

The third project is our digester. We are taking the solids that we are removing from wastewater, including that from this building and every building in the vicinity, including Montgomery, Prince George's, Loudon, Fairfax and Arlington in Virginia and Maryland to the largest advanced wastewater treatment plant in the world, which is Blue Plains. Senator Cardin, I think you will visit us next week when we kick off the Clean Rivers project. And we are spending $450 million to take those solids and to build the largest thermal hydrology project in the world, the first in North America, that will generate 13 megawatts of clean power, which would permanently power 8,000 homes with electricity. That is a project that kicked off earlier in the spring.

That is three projects. What are our messages? First, our industry is green. We are often called polluters, but we don't generate pollution. This is everybody else's pollution that is sent to us that we cleanse on your behalf. And over the last four decades, there has been no sector that has done more to clean the rivers of this Country than the wastewater treatment authorities, or I say Water reclamation authorities.

Second, we won't win if we continue just focusing on water authorities. We are the largest discharger in the Chesapeake Bay with a total of 2 percent of the nutrient load. If you add zero from Blue Plains, 98 percent would still be there. And that is at the cost of $900 million.

Three, there are very high costs at the margin; $900 million for 600,000 pounds of nutrients, we are doing the same thing, getting tighter and tighter and tighter with higher and higher costs.

The flexibility to trade, which is my fourth point, we can figure out flexibility, you can imagine saving our ratepayers, which includes most of the people in this room, a significant amount of money by reducing the cost, we could trade that money to farm fields where reductions could be gained, you could have farmers with the revenue stream, we could save our ratepayers. And my bet is we reduce the amount of nutrients going into the Chesapeake by margins, factors of 10 over what we get from just making smaller and smaller reductions.

And fifth, the jobs in our industry don't go anywhere. Senator Sessions, if you asked how many jobs are in our industry, I say all of them. You can't open a building, a restaurant, a hotel, a manufacturing facility, no enterprise can function without the services we deliver. And the investment that you make as Federal dollars into projects like this, in my judgment, are the best single dollar you will ever spend.

Thank you very kindly.

[The prepared statement of Mr. Hawkins follows:]

Nutrient Pollution: An Overview of Nutrient Reduction Approaches

United States Senate
Committee on Environment and Public Works
Subcommittee on Water and Wildlife

Hon. Benjamin L. Cardin, Chairman

water is life

Testimony of George S. Hawkins, Esq.
General Manager
District of Columbia Water and Sewer Authority

Tuesday, October 4 at 2:30 P.M.
Dirksen Senate Office Building, Room 406

Good afternoon Chairman Cardin, Ranking Member Sessions and members of the Subcommittee on Water and Wildlife. My name is George Hawkins and I am the General Manager of the District of Columbia Water and Sewer Authority – also known simply as DC Water. I'd like to thank you for inviting me to testify today on the advanced innovative projects that DC Water is implementing right in the backyard of our nation's capitol.

Introduction

First, by way of background, DC Water purchases treated drinking water at wholesale from our federal partner, the Washington Aqueduct, which is a unit of the U.S. Army Corps of Engineers. We then deliver this water through our pumping stations and pipes to our retail customers in the District of Columbia – including this very building. We also operate the world's largest advanced wastewater treatment plant, at Blue Plains, for the benefit of our customers in the District and several suburban jurisdictions. We serve more than two million customers in the metropolitan Washington, D.C., area.

I preside over a 1,000-strong workforce charged with maintaining and upgrading a labyrinthine underground system of pipes and valves. To maintain this network in the face of significant economic pressures, declining consumption, stricter environmental mandates, and a customer base that may be unfamiliar is an awesome, humbling challenge. Yet, DC Water is committed to rise to meet today's challenges and plan for tomorrow. We will continue to aggressively pursue federal investment with our regional congressional delegations and national industry partners as we advocate for shared responsibility for the clean-up of the Bay. In addition, we are currently rolling out three major projects: the Clean Rivers Project, the Enhanced Nutrient Removal Project and the Digester Project. All three projects will reduce nutrients discharged into our local waterways, the Anacostia River, the Potomac River, Rock Creek and ultimately the Chesapeake Bay.

Selected Environmental Projects:

Clean Rivers Project

Along with other cities, the District of Columbia faces the problem of how to fix combined sewer overflows (CSO), which happen when heavy rain events overwhelm a system designed generations ago. The nationally accepted solution and one we have adopted, is to build a huge network of tunnels to hold the combined stormwater and sewage until the storm passes and sends it to our treatment plant. Our agreements with the federal government require the design, construction and implementation of various activities and a Long Term Control Plan to be completed by 2025 at a cost of nearly $2.6 billion. These mandated activities are designed to substantially decrease the number of overflows into the local waterways that ultimately flow into the Bay. On average there are approximately 82 overflow events per/year. The Clean Rivers Project is designed to reduce these overflows to 2 events per/year capturing 96 percent of the CSO. Further, there will be a reduction of combined-sewer runoff to the Anacostia River by 98 percent. We have already implemented measures such as tide gates, pumping station improvements, inflatable dams, and screens that filter debris-which have reduced combined sewer overflows by 40 percent.

Also, we are promoting the use of green infrastructure (rain gardens, green roofs and bioswales along streets) to reduce CSOs throughout the District but specifically in the Potomac and Rock Creek watersheds. Green infrastructure provides additional community benefits such as cooler temperature streets, increased economic activity, energy savings and neighborhood revitalization. As evidenced of our commitment, we will undertake a major pilot program of demonstration projects totaling nearly $30 million to evaluate the opportunities of substituting "gray for green" in the Rock Creek and Potomac watersheds.

The Enhanced Nutrient Removal Project

Wastewater treatment plants represent 19% of the nitrogen going into the Bay. Blue Plains Wastewater Treatment Plant is the single largest point source of nitrogen to the Chesapeake Bay. We account for 9.5% of the 20% attributed to wastewater treatment plants (1.8% of the total Nitrogen going to the Bay).

We have long been committed to reducing our effluent nitrogen load. Blue Plains was the first wastewater treatment plant in the Chesapeake Bay watershed to meet its program goals and has met or exceeded them since 2000. The first major step was a voluntary goal program to reduce nitrogen from the plant from 14.1 million pounds/year, a 40 percent reduction from 1985 levels, at a capital cost of over 16 million dollars. The 'best efforts' 8.5 million pound voluntary goal was eventually formalized in the NPDES Permit. By 2010, continuing under a voluntary program beyond any commitments made external to the District of Columbia, DC Water had further reduced effluent nitrogen to about 5 million pounds/year at an additional $100 million capital cost. Thus, for a capital cost of approximately $16 million, DC Water under a voluntary program was able to reduce effluent nitrogen by more than 9 million pounds/year.

In 2009, the USEPA issued an NPDES Permit to DC Water for Blue Plains AWTP requiring a further reduction in effluent nitrogen to 4.4 million pounds/year. The design of the next generation of nitrogen removal the Enhanced Nutrient Removal Program (ENR) is complete and construction started. We broke ground in early 2010. This project will allow Blue Plains to meet the NPDES Permit requirements that will go into effect in January 2015 for nitrogen, as it already does for phosphorus. This reduction of approximately 600,000 pounds of nitrogen, a 2% reduction in the WWTP nitrogen load to the Bay (0.4% reduction of total N), and conversion from a 'best efforts' voluntary goal to a permit requirement will incur a capital cost of $900 million to rate payers. The project is slated for completion in July 2014 and will operate in conjunction with the Clean Rivers Project.

The Digester Project

DC Water will soon be the first utility in North America to use thermal hydrolysis for wastewater treatment, and when completed, Blue Plains will be the largest thermal hydrolysis plant in the world. The carbon and nitrogen collected during the ENR project will be used to produce green energy and a high quality soil product. The thermal hydrolysis and digestion processes convert a portion of the organic matter into electric energy while producing with the remainder a valuable, nutrient rich soil amendment. Using thermal hydrolysis and anaerobic digestion together will generate power to operate half the needs of the plant. Analysts estimate the power generation at approximately 13 megawatts, enough to continuously supply 8,000 homes with electricity. This represents an enormous cost savings to the plant- $10 million annually, which is as much as one third of our electricity costs on an operation that runs every day of the year for 24 hours a day.

In addition to the production of clean, green renewable power, the new process reduces the amount of the remaining solid material to be recycled by more than 30 fewer trucks each day, or nearly 2,000,000 truck miles per year, and reduces truck emissions and gasoline costs. Together with the green energy, these benefits will dramatically decrease the Blue Plains carbon footprint by approximately 50,000 tons per/year. Since Blue Plains is the largest consumer of electricity in the District, this project will in turn have a dramatic effect on the carbon footprint of Washington DC. DC Water will use the high quality soil amendment produced from the digesters for tree planting, landscaping, green roofs and LID projects, greening the city, sequestering carbon, and helping to reduce runoff to the Bay.

The price tag of the complete project is about $400 million, with annual savings of approximately $25 million. The project is scheduled to begin operations in early 2015 Once underway, we will have options to run our city buses with biogas, cut the plant's electric bill by 1/3 saving ratepayers substantial increases per year, trade green credits on the open market and sell the Class A biosolids at any home retail stores. All of this from carbon and nutrients generated by all of us in the DC Water service area, and collected in an effort to restore the Chesapeake Bay. Many eyes will be watching, as leaders in the U.S. water sector eagerly await the results of DC Water's undertaking.

This energy recovery model can be replicated in many states and municipalities across the country.

Summary

In summary, we have three enormous initiatives underway designed to help restore the Chesapeake Bay and push our profession toward sustainability. The Clean Rivers ($2.6B) and the Enhanced Nutrient Removal ($900M) projects are mandated by consent decree and permit, while the Green Energy Digestion Project ($400M) is discretionary. These projects demonstrate DC Water's commitment to the goal we all strive toward – a healthy Chesapeake Bay.

Chairman Cardin, members of the Subcommittee, this concludes my prepared remarks. Thank you again for the opportunity to testify, and I look forward to answering any questions you may have.

Senator CARDIN. Thank you very much for your testimony. We appreciate it very much.

Mr. Budell.

STATEMENT OF RICHARD J. BUDELL, DIRECTOR, OFFICE OF AGRICULTURAL WATER POLICY, FLORIDA DEPARTMENT OF AGRICULTURE AND CONSUMER SERVICES

Mr. BUDELL. Thank you, Chairman Cardin, Ranking Member Sessions. Good afternoon.

I am not here today to question the existence of nutrient pollution problems facing the Nation and the State of Florida. We have impacted water bodies in Florida. We are working very hard to address them, just like all of the sources are and the stakeholders are working together in the Chesapeake, to address the issues facing the Bay.

The question from Florida's perspective today is not whether there is a nutrient pollution problem, but whether the Federal Government is justified in hand selecting one State in the Nation on which to impose Federal regulations. From our perspective, that is the bottom line. Florida doesn't view this action as a partisan issue. You are correct, Mr. Chairman, the story started with EPA under the leadership of the previous Administration.

However, the current Administration continues to embrace the previous Administration's decision in Florida while making the opposite decision in other States.

In EPA's own words, "Florida has developed and implemented some of the most progressive nutrient management strategies in the Nation.' EPA further recognizes that Florida has collected significantly more water quality data than any other State. One-third of the entire national water quality data base the EPA has originates from the State of Florida.

Florida was the first State in the Nation to implement comprehensive urban stormwater management regulations. Our treated wastewater re-use program is a model for the rest of the Country. Our agricultural best management practices program is a critical component of our overall resource management.

By targeting our efforts, Florida has made significant progress in nutrient reduction. Tampa Bay, Sarasota Bay enjoy sea grass populations now not seen since the 1950's. Lake Apopka, a freshwater lake, west of Orlando, phosphorus levels have been reduced by 56 percent, water clarity increased by 54 percent.

Despite these glowing reviews from EPA and Florida's demonstrated commitment, EPA, in direct response to litigation determined in January 2009 that Florida had not done enough and mandated the development of numeric criteria within 1 year. Again, as I said, that determination was made under the leadership of the previous Administration.

But when presented with the same circumstances from Midwestern States facing similar challenges with nutrient pollution as evidenced by the often talked-about dead zone in the Gulf of Mexico, EPA's current leadership declined to make the same determination. They declined to determine that those States needed numeric criteria to deal with the dead zone. That left Florida as the lone State in the Nation to face the imposition of costly Federal numeric criteria.

After determining that Florida needed to develop the criteria, but before the expiration of the 1-year deadline, EPA entered into a settlement agreement with the plaintiffs with no notice to Florida whatsoever and agreed to a schedule for Federal rule adoption; reneging on the time line contained in the original determination and essentially usurping our efforts to develop our own standards. EPA finalized those criteria last December.

This takeover of Florida's criteria development process was further aggravated by the content of EPA's rule. The methods used by EPA to develop its rules are inconsistent with the advice of its own science advisory board. EPA compounded the situation by improperly applying the methods it did use. As a result, in many cases the rule would deem perfectly healthy waters impaired in Florida.

That was just too much for us to deal with. The day after EPA finalized those regulations, Florida's attorney general and the Commissioner of Agriculture filed a complaint in Federal court, challenging the Federal rule. Subsequently, over 30 additional entities, both public and private, have filed complaints in Federal court citing the same shortcomings.

Florida believes strongly that any nutrient reduction strategy should focus on measurable environmental improvement while optimizing the use of public dollars and avoiding costs. In the preamble to their rule, EPA admits they were unable to find a cause and effect relationship between nutrient concentration and biological response for flowing waters like streams and rivers. In the absence of that cause and effect relationship, there can be no guarantee that the high costs spent to reduce nutrient concentration in a stream or river will result in any measurable improvement in the biological condition of that stream or river.

It is important to recognize, as Shellie said, that nitrogen and phosphorus are naturally occurring. They are necessary for the normal biological productivity that occurs in every water body. Determining when too much is present, that is the difficult goal.

Florida believes it is very important to link nutrient concentration with an assessment of biological health of the water body before requiring the implementation of costly nutrient reduction strategies. Without this linkage, implementation of the EPA criteria would have Florida businesses, wastewater and stormwater, utility ratepayers, and food producers spending time and money attempting to reduce nutrient concentrations in some cases to levels below natural background.

Because so many other factors affect nitrogen and how it cycles in the ecosystem and phosphorus, Florida believes the standards are best determined on a site-specific basis.

Inclosing, Florida believes that Florida is best positioned to assess the health of its waters and associated water quality criteria for their protection and restoration. We believe that our track record for the implementation of progressive and successful programs is second to none. In fact, we have developed nutrient rules that address all of the shortcomings of EPA's rule and avoid unnecessary costs, and complete the tasks that the State originally set out to accomplish before Federal intervention.

Florida is poised to adopt its own numeric criteria if only EPA would cease Federal rulemaking. These dual rulemaking activities in Florida serve no public good, create intense legal and political conflict and significantly hamper environmental protection and restoration efforts. Florida has earned the right to exercise the authority envisioned by the Clean Water Act to develop its own water quality standards and implement them through an EPA-approved and predictable process governed by existing State law.

Thank you. I would be happy to answer any questions.

[The prepared statement of Mr. Budell follows:]

Written Testimony of
Richard J. Budell
Director, Office of Agricultural Water Policy
Florida Department of Agriculture and Consumer Services
As submitted to the
U. S. Senate Committee on Environment and Public Works
Subcommittee on Water and Wildlife
October 4, 2011

Chairman Cardin, Ranking Member Sessions and Committee members: Good afternoon: my name is Richard Budell. I am the Director of the Office of Agricultural Water Policy in the Florida Department of Agriculture and Consumer Services. I have been involved in the development and implementation of agricultural water resource protection and restoration programs in Florida for 26 years. I have chaired the Scientific Advisory Group for the Everglades and Florida's Pesticide Review Council. I have advised Florida's Governor and Department of Environmental Protection on issues ranging from the protection of Florida's coastal waters and estuaries to the designated use classification of Florida's surface waters. I recently concluded service on a National Research Council Committee evaluating the nutrient reduction strategies being employed to improve water quality in the Chesapeake Bay. I am pleased to have the opportunity to share with you my Department's perspective on key aspects of the U.S. Environmental Protection Agency's (EPA) final Numeric Nutrient Water Quality Criteria for Florida Springs and Inland Waters that were adopted this past December.

I am not here today to question the existence of nutrient pollution problems facing this nation and the state of Florida. We do have impacted and impaired water bodies in Florida and we are working hard to address them, just as EPA and the states around the Chesapeake are working hard to address nutrient pollution in the Bay. The question is not whether there is a nutrient pollution problem, but whether the federal government is justified in hand-selecting one state in the nation on which to impose federal regulations that impart costs on all households. Florida does not believe that EPA's actions represent a partisan issue. This story started with EPA under the leadership of the previous administration. However, the current administration continues to embrace the previous administration's decision in Florida, while making the opposite decision in other states.

In the EPA's own words, "Florida has developed and implemented some of the most progressive nutrient management strategies in the Nation." Florida is one of the few states that has implemented a comprehensive framework of accountability that applies to both point and non-point sources and provides authority to enforce nutrient reductions. The EPA has also acknowledged that Florida has placed substantial emphasis on the monitoring and assessment of its waters and, as a result of this commitment, has collected significantly more water quality data than any other state. Greater than 30% of all water quality data in the EPA's national water quality database comes from Florida.

Florida was the first state in the nation to implement comprehensive urban storm water management regulations. Florida's treated waste water reuse program is a model for the rest of the country. Our agricultural Best Management Practices program is firmly rooted in state law, is backed by sound science and is a critical component of Florida's overall water resource management programs. These practices have been implemented on over eight million acres of agricultural and commercial forest lands in Florida.

By targeting its efforts and resources, Florida has made significant progress in nutrient reduction and water resource restoration. Examples range from Tampa Bay, where sea grasses have returned to levels not seen since the 1950s and now cover 30,000 acres, to Lake Apopka, where phosphorous levels have been reduced by 56% and water clarity increased by 54%.

Despite these glowing reviews and Florida's demonstrated commitment to water resource protection and restoration, EPA, in response to litigation, "determined" in January of 2009 that Florida had not done enough and mandated the promulgation of numeric nutrient water quality criteria within one year. Again, that determination was made under the leadership of the previous administration. When presented with the same circumstances for Midwestern states facing similar challenges with nutrient pollution, as evidenced by the often-talked-about dead zone in the Gulf of Mexico, EPA's current leadership declined to take such action. This left Florida as the lone state in the nation to face imposition of very costly federal environmental regulation.

After determining that Florida needed to develop numeric criteria, but before the expiration of the one-year deadline, EPA entered into a settlement agreement with the plaintiffs and agreed to a schedule for federal rule adoption, reneging on the timeline contained in its previous determination and usurping Florida's ongoing efforts to develop its own standards. EPA subsequently set criteria for Florida in December of 2010.

This takeover of Florida's nutrient criteria development process was further aggravated by the content of EPA's rule. The methods used by EPA to construct its rules are inconsistent with its own guidance documents and the advice of its Science Advisory Board. EPA compounded this situation by improperly applying the methods it did use. As a result, in many cases the rule would deem healthy waters as impaired. In response to these issues, Florida Attorney General Pam Bondi and Commissioner of Agriculture Adam Putnam filed a complaint in federal court challenging the rule. More than 30 other entities, both public and private, have subsequently filed similar federal complaints against the EPA and their Florida numeric nutrient criteria, citing the same shortcomings.

Florida believes strongly that any nutrient reduction strategy should focus on measurable environmental improvement, while optimizing the use of public dollars and avoiding costs that have no environmental benefit. In the preamble to its rule, EPA admits that it was unable to find a cause-and-effect relationship between nutrient concentration and biological response for flowing waters, like streams and rivers. In the absence of that cause-and-effect relationship, there can be no certainty that the money and human resources devoted to reducing nutrient content in a stream or river will result in any measurable improvement in the biological condition of that stream or river.

It is important to recognize that nitrogen and phosphorous are naturally occurring and are necessary for the normal biological productivity of water bodies. Determining when too much human-induced nitrogen or phosphorous is present is difficult. Therefore, Florida believes that it is very important to link numeric criteria with an assessment of the biological health of a water body before requiring the implementation of costly nutrient-reduction strategies. Without this linkage, implementation of the EPA criteria would have Florida citizens, businesses, waste water and storm water utility rate payers and food producers spending time and money attempting to reduce nutrient concentrations in some cases, to levels below natural background. Because so many other natural factors (e.g., stream size and velocity, light penetration) affect how nutrients impact ecosystems, Florida believes that nutrient management decisions are best determined on a site-specific basis using biological indicators, rather than by applying generic criteria that may bear little relationship to natural conditions.

In all estimations, implementation of numeric criteria is an expensive proposition; care must be taken to avoid unnecessary efforts that do not add measurable value to water resource protection and restoration.

Cost is an issue around which there is considerable debate. EPA estimated the range of total costs to implement the Florida nutrient criteria at between $135 million and $236 million annually. The Florida Department of Agriculture and Consumer Services, working in cooperation with the University of Florida Food and Resource Economics Department, estimated the implementation costs just for agricultural land uses at between $900 million and $1.6 billion annually. Preliminary estimates from the Florida Department of Environmental Protection peg the implementation costs for urban storm water upgrades alone at nearly $2 billion annually. A study commissioned by a large coalition of Florida-based public and private entities estimated the total implementation costs at between $415 million and $4 billion annually. The wide variability in this latter estimate is, in part, due to not yet knowing the rule requirements. During EPA's rulemaking effort, the agency did not address implementation expectations. They remain unaddressed.

From an agricultural perspective, I can tell you without question that virtually no sector of Florida agriculture can comply with the final EPA nutrient criteria without the implementation of costly edge-of-farm water detention and treatment.

Florida is pleased that the EPA has agreed to request that the National Research Council convene a panel to review all of the economic studies and render an opinion on the likely costs of implementation.

In closing, Florida believes that Florida is best positioned to assess the health of its waters and establish associated water quality criteria for their protection and restoration. We believe that our track record for the implementation of progressive and successful water resource management programs is one of the best in the country and demonstrates the commitment and determination to further its comprehensive program through the development and implementation of state-derived numeric nutrient criteria. In fact, Florida has developed draft nutrient rules that address all of the shortcomings of EPA's rule, avoid unnecessary cost impositions and complete the task that the state originally set out to accomplish before federal intervention. Florida is poised to adopt its own numeric criteria, if only EPA would cease federal rulemaking. These dual rulemaking activities in Florida serve no public good, create intense legal and political conflict and significantly hamper environmental protection and restoration efforts.

Florida has earned the right to exercise the authority envisioned by the Clean Water Act to develop its own water quality standards, and implement them through an EPA-approved and predictable process governed by existing state law.

Thank you.

Environment and Public Works Committee Hearing
October 4, 2011
Follow-up Questions for Written Submission

Questions for Budell

Questions from:

Senator Barbara Boxer

1. Your testimony criticizes EPA's approach in developing numeric criteria. However, isn't it true that many of the numeric standards developed by EPA are the same or even less stringent than standards proposed by the State of Florida in the fall of 2008?

EPA's numbers are similar to those that had been developed by Florida. What's true is that where the numbers were not based on a cause and effect relationship between nutrients and waterbody health, Florida had proposed to link the numbers with additional measurements of the biological health to assure that proper decisions were being made regarding nutrient pollution. Including checks and balances regarding nutrient concentrations and biological health will assure that nutrient controls are implemented where necessary. Nutrient controls may be needed where nutrient concentrations are below the numbers, but the biological health indicates impairment. Conversely, nutrient controls may not be needed where concentrations are above the numbers, but the biological health indicates a healthy waterbody without impacts. In either circumstance, the proper decisions are made regarding the need for additional regulatory controls only if there is the linkage between numeric standards and a biological assessment of the water body.

2. Your testimony states that "Florida is poised to adopt its own numeric criteria...and has earned the right to exercise the authority envisioned by the Clean Water Act..."

   Isn't it true that EPA's response to Florida's petition to withdraw the numeric criteria rulemaking made clear that EPA would withdraw its rulemaking if the State finalizes and implements its own rules. EPA's response stated,

   > "The State was authorized by the CWA to adopt numeric nutrient water quality criteria before EPA's January 2009 determination, and has remained authorized...If FDEP adopts and EPA approves protective nutrient criteria to address the concerns underlying our determination and rule, and if such criteria enter into legal force and effect in Florida, EPA will promptly initiate rulemaking to repeal the corresponding federally promulgated numeric nutrient criteria."

What's true is that Florida petitioned EPA to rescind their 2009 necessity determination and withdraw their rule based on the March 16, 2011 "nutrient management framework" memo from Nancy Stoner to all Regional Administrators. Florida clearly exceeds all of the 8 criteria included in that memo and asked the Agency to recognize that fact and place Florida back on a level playing field with the rest of the nation. EPA chose to respond to the petition by evading the request and downplaying the significance of the March 16 memo.

What is also true is that EPA is subject to a settlement agreement, which they voluntarily entered into without consulting Florida, which contains fixed deadlines that would lead to parallel rulemaking in Florida by the State and Federal government. Parallel rulemaking at both levels is very time consuming and costly for the interests of Florida who then have to marshall resources to track two complicated rule development efforts, comment during the administrative processes, and interact with two completely different government Agencies with very different administrative procedures.

3. In your testimony, you state that nutrient management decisions are best made on a site-specific basis, rather than by general criteria.

   Isn't it true that EPA's final rule allows the State to establish "site-specific alternative criteria" for individual water bodies that would substitute locally-developed nutrient standards for EPA's proposed numeric nutrient standards?

What's true is that the final rule authorizes EPA to set site-specific alternative criteria through a petition process implemented by the Regional Administrator of EPA's Region 4 office. One petition was filed last March which has not been acted upon by the Region. No nutrient SSAC have been set anywhere in the nation by EPA and the rule provides little explanation on how such SSAC's would be developed and adopted.

Questions from:

Senator Benjamin Cardin

1. At our recent hearing, you testified that the EPA's numeric nutrient standards are overly burdensome for the agriculture industry in Florida. Agriculture is Florida's second-largest industry, while tourism is Florida's largest industry. Is it possible that the cleaner water will result in a benefit to tourism, and that this benefit will outweigh any economic burdens?

There is no evidence that Florida's tourism industry has been negatively affected by water quality issues. Florida has the most comprehensive and progressive water quality protection and restoration program in the country. [See the Florida Department of Environmental Protection's Petition to EPA at http://www.dep.state.fl.us/water/wqssp/nutrients/meeting-arch.htm. There are specific waterbodies where nutrient clean-up is desired, but the EPA rule will deem many healthy waters impaired. It makes no sense to require costly nutrient reduction efforts simply to meet a number as the EPA rule would require.

2. Do you think a nutrient-trading program would be an effective way to manage and reduce nutrient pollution? Why or why not?

Nutrient trading programs could be effective as long as the nutrient reduction is achieved in the same watershed in which the credit is generated. To protect a particular water body all credits and reductions must be achieved in the water shed that supplies runoff or groundwater to that water body.

Questions from:

Senator James Inhofe

1. Why is a single number for nitrogen or phosphorus usually not an accurate indicator of adverse ecological or water quality effects? Why do you believe EPA is continuing to press states to adopt a single, one-size-fits-all number? Is using a single-number approach scientifically sound?

A single number for nitrogen or phosphorus is not an accurate indicator of ecological effect because many factors other than nitrogen or phosphorus concentrations impact the biological heath of a water body. Factors such as habitat, flow velocity, depth and light penetration are every bit as important to the biological diversity of a water body as the nutrient concentration of that water body. EPA prefers a single number for water bodies because it is an easier regulatory approach to implement. If you violate the number you are in violation of the standard. Unfortunately, such a simplistic approach is not reflective of the heterogeneity that Mother Nature provides us in the real world. The use of a single number, for all of the reasons stated above, is not scientifically sound.

2. EPA "strongly believes that states should lead the effort" to reduce nutrient pollution, and EPA is "committed to finding collaborative solutions" and building "partnerships with states and collaboration with stakeholders." From your vantage point, and judging by EPA's actions, is EPA being "collaborative" and willing to let stats "lead the effort" in dealing with nutrient pollution? Why or why not?

By entering into a settlement agreement with the plaintiffs to the original 2008 lawsuit, without any consultation with Florida, the EPA did not demonstrate a "collaborative" approach. Instead they pursued the current approach of finalizing nutrient criteria for Florida. Furthermore, the Federal rule-making process was not transparent, nor receptive to the implementation concerns voiced by Florida stakeholders on several occasions.

3. Why is using a "consensus " approach, where you have buy-in from the regulated community, important in developing standards and an overall water quality strategy for addressing nutrients?

To be effective, water quality criteria must be implemented. To be implemented, the criteria must be based on sound science and be supported by the entities that must comply with them. Implementation is much more likely to succeed if those who must comply with the criteria are part of the process to develop them. Quite simply, every entity wants to know how they would be affected.

4. On March 16, 2011, Nancy Stoner sent a nutrient management "framework" memo to EPA regions outlining "Recommended Elements of a State Framework for Managing Nitrogen and Phosphorus Pollution." When asked at a Congressional hearing as to whether EPA was intending on imposing Federal nutrient standards on any other states beyond Florida, EPA Administrator Lisa Jackson referenced this memo and indicated that if a state met these guidelines, the Agency would be unlikely to impose its own standards on a state. Does Florida meet these guidelines? In light of this, has the state asked EPA to withdraw its requirements and allow the state to resume moving forward on its own standards? What is EPA's response?

Florida exceeds all of the elements of the Nancy Stoner "framework" memo. Based on the fact that Florida exceeds all of the criteria in the March 16, 2011 memo, Florida petitioned the EPA asking that they rescind their 2009 necessity determination and begin the process of withdrawing their rule establishing nutrient criteria for Florida. In exchange, Florida committed to promptly develop and adopt state numeric criteria for submission to EPA for approval. EPA's response was to acknowledge that Florida had the right to develop its own criteria and to defer any decision on rescinding their necessity determination. In addition, they downplayed the significance of the "framework" memo which Florida believes is in direct conflict with Administrator Jackson's testimony.

5. Was Florida consulted prior to the issuance of EPA's March 16, 2011, nutrients "framework" memo? How could EPA improve the "framework" memo to ensure that they are emposering states to tackle these issues in a scientifically sound way?

Florida was not consulted on the content of the "framework" memo. What EPA does to change the "framework" memo is of little consequence when it appears that the memo will not be used to inform Agency decisions. EPA's response to Florida's petition succinctly stated that the memo would not be used to guide the Agency's decisions in our State. What would be more meaningful would be for EPA to embrace their memo and treat states as a true partner in efforts to control nutrient pollution, including the development and implementation of meaningful nutrient criteria. The EPA fails repeatedly to recognize that Mother Nature does not present the states with problems that match the EPA's idea of what water quality criteria should be.

6. Can you describe examples of practices agricultural producers implement under Florida's agricultural BMPs program? Have these been shown to lead to reduced nutrient levels in Florida waterways?

One of the most effective practices is the installation of water control structures that allow landowners to better manage the rate and timing of storm water movement across their property. Another effective practice is fencing along critical portions of waterways to exclude animals from entering streams or ditches. Both of these practices have been shown to decrease nutrient loads entering waterways.

7. Is there anything else you would like to add to the record?

Florida continues to be perplexed by the EPA's decision to treat Florida differently than all other states in the nation. The only conclusion that Florida can draw from this unprecedented action is that the EPA arrived at this decision strictly for the purposes of settling a lawsuit. No state in the nation has a more comprehensive water quality protection and restoration program. Why has the EPA continued to single out Florida as the only state in the nation where they have determined that it is necessary to adopt numeric nutrient criteria in order to satisfy the requirements of the Clean Water Act?

Senator CARDIN. Let me thank all five of you. I thought this panel was extremely helpful. I thank you for your testimony, and I said before, thank you for your patience.

Mr. Buchsbaum, your numbers on the anglers I found to be very impressive. I would ask that whatever documentation you have of the potential economic damage to our communities as a result of nutrient pollution, I think it would be helpful. I know in the Chesapeake Bay how important the recreational and charter industries are for our economy. And I don't know if there are any reports we have that demonstrate the economic losses. But if you have information on that, I think it would be very helpful for us to get it.

Mr. BUCHSBAUM. We would be happy to supply that. Of course, the information we have our charter boat captain, we have lost 100 jobs already in Lake Erie, at least, and more to follow.

Senator CARDIN. That is sad. But it is important that we understand, this is not just about public health issues, it really has a direct economic impact.

Mr. BUCHSBAUM. We will provide more information.

Senator CARDIN. Jobs are our key point right now.

Ms. Chard-McClary, I appreciate your testimony. I appreciated your giving me one more example of Oklahoma that I can at least relate to. We had the same discussion on fracking.

But the TMDLs seem to be working well in your State, from your testimony. As you point out, it is individually determined. So it is a tool that is used locally to help you deal with your issues. I liked your idea of too many calories. We all like calories, we all need calories. But when we have too many, it causes a problem. And the TMDLs is a pollution diet, that is exactly what it is. And it seems to be an effective tool. But again, it needs to be tailored to the individual circumstance.

Although the one in the Chesapeake Bay has gotten a lot of attention, there are literally thousands of TMDLs that are working around our Nation that are all used in a way to deal with the local circumstances.

Mr. Maravell, I must tell you, I found your testimony to be extremely exciting. The number of tools that you have used, the number of methods that you have used in order to manage the ENVIRONMENTAL risks of farming I found to be very encouraging. You understand that it is not going to be one simple method to deal with the challenges you have as a farmer.

My question for you is this. You rightly so have developed a market. I think a lot of consumers want to support your type of activities. They are willing to go out of their way to support products that are produced in an organic manner, because we want to participate. Is there a cost that you pay on competition because of the way that you are farming that, if it were not for people wanting to buy organic, it could cause you a competitive problem in selling your products?

Mr. MARAVELL. This is a question that comes up quite frequently. What we do is, we don't try to maximize our returns in any 1 year. We try to optimize them over the years, which is why our farming system is a little bit resilient in many different ways. One of the ways is, you have the vagaries of weather, but we also have the vagaries of circumstances in foreign lands and other things that raise the cost of petroleum, for example. We rely less on that for our nutrients, basically not at all. So there are some years where we make out a little bit better and other years where we don't. The research has shown that generally speaking, in drier years, the type of systems that I employ are going to do better. I can tell you that when there is drought assistance relief programs in our county, I can never qualify, because in the dry years, my average yields are above the county averages.

The other thing I will point out is that some of our products would be considered to be priced a little bit higher than comparable products not produced with organic methods. And some of my products are marketed very competitively, and might even be considered below conventional. You say, well, how does that happen? Well, again, it is the vagaries of the marketplace, a little bit. But it is having the connection to the consumer Having that direct farmer to consumer connection allows certain efficiencies to come about. And because we market a variety of different products, we are able to cross-sel those products to people who come out to the farm, and as you say, want to support and want to participate in the type of farming that we do, and who want to enjoy the benefits of the Chesapeake Bay at the same time.

Senator CARDIN. Farming is, someone has to have a real motivation to be a farmer today. It is not easy. And there is satisfaction with what you do with the land. It seems to me you must have an increased level of satisfaction, knowing that you are not only producing a great product for the market, but you are doing it in a way that will help our future. Thank you for doing it. I appreciate it.

Mr. Hawkins, just quickly if I might, very impressive testimony. The type of investments you have made are incredible, what you have been able to do. Thank you for the water, I drink it every day when I come to Washington. I appreciate that. And thank you for what you do under a very difficult environment.

But you raise a very interesting point. I want to get back to the nutrient trading program one more time. We need to reach certain levels to get that marginal savings through the improvements to the way you treat waste. It is very expensive. Whereas if we could use some of the practices that Mr. Maravell uses, it is a lot less expensive, and municipalities are willing to, I would think, buy nutrient credits so that extra marginal $900 million cost, some of that can be saved and Mr. Maravell would like to have some of that money in his pocket for perhaps using seasonal crops.

Mr. HAWKINS. I think you can't help but look at the numbers. When my compatriot from the Department of Agriculture mentioned in the prior panel that there were $20 million committed in the Chesapeake Bay, a six-State area, that is a significant number. But just compare it to the $900 million that we will spend to reduce 600,000 pounds of nutrients. I don't think there is any question that you could spend $900 million a lot better than making our plant at the margin that much better, except, this is what we have always done. We know how to do it, we know where the regulation, where the point source, I hope you will come visit, Senator Sessions. We would love to have you. I guarantee you would be fascinated to see the scale of it.

But the notion that you could trade and get reductions where we know the larger sources are at lower cost, and achieve a better outcome, and save urban ratepayers who are facing these skyrocketing bills all at the same time, it is an outcome that only has good potential. So I encourage, I know you have, and I encourage you to keep at it.

Senator CARDIN. It is clearly a win-win situation. I would hope that we could move, we think there is some authority within the agency to do this today. We have encouraged them to do it. But if they need extra help from Congress, I would hope that is one area that we could move forward on.

Senator SESSIONS. Thank you. Very interesting panel, and I am glad we have an expert witness here. I don't know if you are under oath, but this water is safe to drink and the taxpayers don't need to buying bottled water for the people in Washington.

Mr. HAWKINS. Hear, hear. You are exactly right. Thank you.

Senator SESSIONS. I think you are correct, and I agree with you on that.

Plus, in plastic, I always thought it rather odd that the people who attack the high price of gasoline were perfectly willing to go into a gas station and buy a bottle of water that cost about three times as much as gasoline costs per ounce.

Well, Mr. Buchsbaum, in your report you gave us, it indicated that Lake Erie phosphorus loads in this chart are slightly below the agreement target load, and yet you still have this kind of algae growth. Do you attribute the algae to phosphorus levels or multiple factors?

Mr. BUCHSBAUM. Definitely multiple factors. But definitely phosphorus levels. The phosphorus loads vary, so sometimes they are up, sometimes they are down. The key statistic isn't in that chart, it is in another chart in the report, which indicates that soluble reactive phosphorus, that is the phosphorus that is actually most available to biological growth, that has been in a steady increase for the last few years. And it is that phosphorus which is actually the thing that is causing the most of the algae blooms.

There are other factors involved. The temperature of the lake is higher. You also have invasive mussels that are messing up the system a bit. But in fact, it is the soluble reactive phosphorus. That is still unclear exactly where that comes from. But they believe it is a combination of, well, there are some biological interactions that are increasing it.

But it is also certain farming practices that were encouraged for conservation practices, including no-till. It looks like we may need to make some slight adjustments to those. Because the longer that the phosphorus is left in the soil, the more it binds with the soil. So then when you have soil washing in, we are having larger storms, so as the larger storms wash the soil into the rivers and then that is carried out into Lake Erie. That soil includes soluble reactive phosphorus at levels we didn't have before.

Senator SESSIONS. I think these are complex issues, and I do think science can help us best address how to confront them.

Mr. Budell, I was, as a former attorney general of Alabama, and a former United States attorney in litigation for the United States, I was a bit taken aback that you were not consulted when EPA settled what was, I assume, a Federal lawsuit over pollution? Is that where the agreement arose?

Mr. BUDELL. Florida was not a party to the lawsuit.

Senator SESSIONS. Right.

Mr. BUDELL. It was a lawsuit from private ENVIRONMENTAL community with EPA.

Senator SESSIONS. But you were taking a lead in controlling nutrient levels, and emissions into the waters, and this lawsuit dealt with that issue, is that correct?

Mr. BUDELL. That is correct.

Senator SESSIONS. And as a matter of courtesy and propriety, you felt like, if not legality, that you should have been consulted in this process?

Mr. BUDELL. It would have been an indication of the cooperative nature of working together with EPA to develop numeric criteria to have been consulted in a consent decree, yes.

Senator SESSIONS. Well, I have been involved, and I have seen litigation that occurs when people are kind of proud, too quick to settle a lawsuit because they think the court is going to tell them to do what they would like to do anyway. So at any rate, EPA is able to negotiate a settlement that bound you, and you were not able, you were not asked to participate, and I don't think that is good Federal-State cooperation, frankly.

Now, you are still waiting on an answer concerning the petition that Florida has made to the EPA to withdraw its nutrient rule? You have not gotten a formal answer yet?

Mr. BUDELL. That is correct. The letter that was in response to the petition that was sent to EPA in April was really a non-response. It was as Ms. Stoner described it, it was, they are still evaluating, they are encouraging Florida to move forward with the numeric rule, numeric criteria development. But they have not decided yet whether they are going to withdraw their rule or not.

Senator SESSIONS. Are you confident that the EPA has used the best available science in its nutrient rulemaking process?

Mr. BUDELL. No.

Senator SESSIONS. Explain your concerns about that. I think you are entitled to express them.

Mr. BUDELL. As I stated in my comments, what we believe should be the approach that is appropriate and provides States with the flexibility and does build onto good science is to use numeric criteria as a guideline, as a screening tool to evaluate the heath of water bodies. But you must pair that numeric criteria with the biological assessment to look at the ecology of the water body itself, to see if it is healthy. If it supports a healthy population of flora and fauna but exceeds the numeric criteria by a tenth of a part per million or two-tenths or three-tenths or four-tenths, does it really make sense to spend money and time and resources to control the nutrient concentration when the biology is perfectly healthy? We think not. We think that is a flexible tool to target your resources to water bodies that are truly biologically impaired, where you can focus those efforts and gain the maximum amount of benefit for the least amount of money, optimizing the public dollars that are available for this kind of a project.

Senator SESSIONS. Well, and just for the record, you in the State of Florida, attempts, I assume every day, to utilize the Resources you have to get the maximum benefit to the waters of your State. Is that correct? And you make decisions that you think maximize, considering some of the factors Mr. Hawkins referred to, to get the maximum positive impact from your efforts that you expend, is that correct?

Mr. BUDELL. That is correct, we do that every day.

Senator SESSIONS. And I guess it is your concern that the ENVIRONMENTAL Protection Agency, through its more numerical system, will not direct the resources most effectively?

Mr. BUDELL. The situation that we are facing now is that to date, we have proposed to develop a numeric nutrient criteria model in Florida that couples nutrient criteria guidelines, numeric guidelines with an assessment of the biological health of the water body. And to date, that proposal has been rejected by EPA.

Senator SESSIONS. Thank you, Mr. Chairman. You have been very kind. I am late to another meeting, and I just want to express my appreciation again to the panel members. We appreciate your written testimony and look forward to working together.

Senator CARDIN. Senator Sessions, I appreciate very much your active participation here. This hearing has gone longer than we had originally scheduled it, and I very much appreciate your active participation. This is an area that, I am going to ask one more question, but it will be pretty brief.

First, Mr. Budell, let me point out that I hope that Florida and EPA can work this out. I heard today from EPA that they want to sit down, they are trying to, they believe that there isn't as much division and they hope that they will be able to reconcile the issues because they want local control. That is EPA's preference on these issues.

And I come to this, and I will give you a chance when I finish my comments, I come to this knowing full well that many of the standards developed by EPA are the same or even less stringent than the standards proposed by the State of Florida in the fall of 2008. Then when the EPA issued its numeric nutrient water quality criteria in January 2009, it included a statement from Deputy Secretary Michael Sole from the State of Florida recognizes that more needs to be done to address nutrient pollution in our rivers, streams, lakes and estuaries. These actions will help our State and all our stakeholders prevent and better manage sources of nitrogen and phosphorus from entering our waters.

That was included, that quote from Michael Sole was included in the release when numeric standards were announced by the Environmental Protection Agency. So it seems to me in 2009 we were pretty close together and something has happened since that date that has created a problem. I am going to ask unanimous consent, without objection, to include in the record the full copy of the release of January 16th, 2009, and several editorials from the Orlando Sentinel, from Florida Today and from the St. Petersburg Times, relative to this subject matter.

[The referenced information was not received at time of print.]

Senator CARDIN. Also complimentary of the use of the tools and numeric standards for dealing with the nutrient problems of Florida waters.

I put that all in context, because it is our hope that Florida would work with EPA. And I know it takes two sides to do it, believe me, I do. And work out a way that we achieve the results that I think both Florida and EPA would like to see achieved in a manner which gives comfort to the State that we are proceeding in the most cost-effective way based upon good science to bring down the nutrient problems of our waters in Florida. If you would like to respond, that is fine.

Mr. BUDELL. Briefly. Only to say that we too want to work out an agreement with EPA. We want to propose to them criteria that they can approve. We think the best way to do that is to bundle the numeric guidance number with the biological assessment of the water body to help us determine which water bodies are truly impaired.

You have heard Ms. Chard-McClary talk about the variability from water body to water body, nutrient concentration in one water body causes an impairment, and in an adjacent water body, it may not. They are very site-specific. And we believe that in order to use those criteria as screening tools, you must couple it with a biological assessment of the water body before you determine that a Water body actually has to have nutrient reduction measures employed.

We don't doubt that numeric criteria are a tool that can be used to help us screen water bodies for impairment. But they don't necessarily equate to impairment. And meeting the number just to meet the number oftentimes is a waste of money.

Senator CARDIN. I think I understand your point. And I take it that was known in 2009, and I understand your position today. I really do. So I think this is an area that I hope will be resolved. I think we all understand the dangers of nutrient pollution and the need for aggressive action. And we absolutely need the cooperation of our States working with all partners, including the EPA.

Again, I found this panel to be extremely interesting and helpful. I really do applaud the efforts being made by you all to try to improve the nutrient issues. From our neighbors here in the District, I must tell you, the District has been one of the strongest partners on the Chesapeake Bay partnership. We do applaud, from the very beginning, the District has been one of the leading partners in taking responsibility for the Chesapeake watershed. Obviously the challenges you have at Blue Plains is a significant part of that issue.

Mr. Maravell, just one more time, I appreciate a Marylander being here. And what you are doing as far as leading on not only an efficient farming operation but a green farming operation is certainly encouraging.

To all of you, thank you very much for being here. With that, the committee will stand adjourned.

[Whereupon, at 4:39 p.m., the subcommittee was adjourned.]

[Additional material submitted for the record follows.]

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

OFFICE OF
WATER

Mr. Ronald F. Poltak
Executive Director
New England Interstate Water Pollution Control Commission
116 John Street
Lowell, Massachusetts 01852-1124

Dear Mr. Poltak:

Thank you for your January 3, 2011 letter expressing concern about the Environmental Protection Agency's (EPA or Agency) emphasis on state adoption of numeric nutrient criteria for both nitrogen and phosphorus, and EPA's position on independent applicability when assessing for use attainment and listing waters for nutrient impairment. EPA appreciates and recognizes the important efforts that states in EPA Regions I and II have taken to address nitrogen and phosphorus pollution, and I hope that this letter responds to your questions.

Nitrogen and phosphorus pollution poses a significant water quality and public health concern across the United States, impacting water supplies, aquatic life, and recreational water quality. EPA's regulations at 40 CFR 131.11 specify that criteria "must contain sufficient parameters or constituents to protect the designated use." Therefore, EPA considers state adoption of numeric criteria for nitrogen and phosphorus, the causal parameters directly responsible for eutrophication in immediate and/or downstream waters, a priority. Adoption of numeric criteria for nitrogen and phosphorus will facilitate and expedite the protection of waters by assisting states in identifying and listing impaired waters, developing total maximum daily loads, and writing National Pollutant Discharge Elimination System permits. Numeric criteria for nitrogen and phosphorus can also further improve water quality by assisting nonpoint sources in best management practice implementation.

In your letter, you propose that states should target only the limiting nutrient parameter -- either nitrogen or phosphorus -- unless it is demonstrated that both are the cause of non-attainment. EPA believes the adoption of numeric criteria for both nitrogen and phosphorus is necessary since generalizations about the limiting nutrient are not always appropriate. For example, lakes are not always phosphorus-limited and estuaries are not always nitrogen-limited, and the limiting nutrient in a waterbody or watershed often fluctuates seasonally and/or spatially. Additionally, to meet the requirements of 40 CFR 131.10(b), a state "...shall ensure that its water quality standards provide for the attainment and maintenance of the water quality standards of downstream waters." Since either or both nitrogen and phosphorus can be the direct cause of impairment in either near-field or downstream waters, states should adopt numeric criteria for both parameters. To be consistent with 40 CFR 131.10(b), states should ensure and demonstrate how the in-stream numeric criteria for nitrogen and phosphorus would be protective of downstream waters.

States may assess waters for nutrient response parameters (e.g., chlorophyll-a, Secchi depth, dissolved oxygen) in conjunction with nitrogen and phosphorus; however, relying solely on a response parameter and/or biological assessment to determine impairment may not sufficiently protect all waters. Assessing waters by evaluating the pollutants directly causing impairment (nitrogen and phosphorus) helps ensure protection of both near-field and downstream waters, and also helps prevent degradation of water quality. Some waterbodies may not exhibit a local response to nitrogen and phosphorus loading due to site-specific characteristics (e.g., turbidity limits light availability and therefore primary production), the season (e.g., lower winter temperatures limit productivity), or the natural lag-time between nitrogen and phosphorus loading and a biological response. Even when a local response has not been clearly demonstrated, these waters may be discharging nitrogen and phosphorus loads to downstream waters that may exhibit a response to nitrogen and phosphorus. EPA recognizes that there is analytical, spatial, and temporal variability associated with environmental data, that should be considered in deriving numeric criteria for nitrogen and phosphorus. EPA can work with states to adjust the state-adopted causal parameter criteria to account for site-specific conditions that continue to assure attainment of applicable water quality goals.

Your letter proposes an integrated approach to assess waters for nutrient impairment, in which a waterbody would not be listed as impaired until after a nutrient response or impact is observed, even if nitrogen and/or phosphorus concentrations exceed the relevant standard. The Agency's primary concern with this approach is that waiting for visible algal growth or an alteration in the biological community ensures that the designated use is already impaired before action is taken to reduce nitrogen and phosphorus loadings. It takes a significant amount of time and resources for a waterbody to recover once visible signs of nitrogen and phosphorus enrichment are demonstrated. Assessing for nutrient causal parameters, and implementing the necessary controls if the causal criteria values are, or have the potential to be, exceeded, will help prevent a nutrient response. Furthermore, states must consider all relevant standards in assessments, in order to be consistent with Clean Water Act Section 303(d)(1)(A) which states that "each state shall identify those waters within its boundaries for which the effluent limitations required by section 301(b)(1)(A) and section 301(b)(1)(B) are not stringent enough to implement any water quality standard applicable to such waters." EPA provides states flexibility in adjusting the frequency and duration components of numeric nutrient criteria, and is amenable to working with states to develop a scientifically defensible approach that incorporates nitrogen and phosphorus numeric criteria, nutrient response parameters, and where appropriate, biological assessments, is protective of near-field and downstream waters, and is consistent with the Clean Water Act and its implementing regulations.

EPA adheres to the Clean Water Act and its implementing regulations when reviewing new or revised water quality standards. Therefore the Agency encourages states to be in frequent communication with EPA throughout the criteria derivation process to allow for early opportunities for guidance and comments on the state's approach. EPA regulations at 40 CFR Part 131.6(b) provide that states must submit to EPA the "methods used and analyses conducted to support water quality standards revisions." States are afforded flexibility in how they derive numeric nitrogen and phosphorus criteria, and assess waters for use attainment. Importantly, the methods used and rationale must be scientifically sound, as well as clearly and thoroughly described and documented in the water quality standards submission or supporting documentation. A state's numeric nutrient criteria must protect the water's biological and chemical characteristics, ensuring that the water achieves its most sensitive designated use, as described in 40 CFR Part 131.11. Further, since designated use protection is largely contingent upon a criterion's duration and frequency components, EPA regards these components as key to a complete water quality standards submission.

I appreciate your interest in addressing nitrogen and phosphorus pollution issues in Regions I and II, and taking the time to express your views and those of the New England Interstate Water Pollution Control Commission. EPA looks forward to continuing to work with states and learn from their experiences in developing and adopting appropriate numeric criteria for nitrogen and phosphorus. Again, thank you for your letter.

If you have additional questions or concerns please contact me or Ephraim King, the Director of Office of Science and Technology, at 202-566-0430, king.ephraim@epa.gov.

Sincerely,

Nancy Stoner
Acting Assistant Administrator

Congress of the United States
Washington, DC 20515

September 21, 2011

The Honorable Lisa P. Jackson
Administrator
United States Environmental Protection Agency
1200 Pennsylvania Ave, NW
Washington, DC 20460

Dear Administrator Jackson:

It has come to our attention that the Environmental Protection Agency (EPA) recently denied the Minnesota Center for Environmental Advocacy's (MCEA) petition requesting that the EPA set numeric nutrient water quality standards for the Mississippi River and the Gulf of Mexico. As representatives of the only state in the nation subject to EPA numeric nutrient standards, we hope that EPA's cooperative approach to the Mississippi River basin signals that EPA will immediately reconsider its unilateral actions in Florida.

In a letter dated July 29th to the Legal Director of MCEA, the EPA outlines several nation-wide efforts the Agency has made to address nutrient loadings throughout the country. The letter states that "the most effective and sustainable way to address widespread and pervasive nutrient pollution in the MARB and elsewhere is to build on these efforts and work cooperatively with states and tribes to strengthen nutrient management programs." Furthermore, the Agency states it is "exercising its discretion to allocate its resources in a manner that supports targeted regional and state activities to accomplish our mutual goals of reducing N and P pollution and accelerating the development and adoption of **state approaches** to controlling N and P." [*Emphasis added.*]

As you know, the State of Florida is the only state that EPA has overtaken with Federal regulations to address nutrients in water bodies. Notably, all of the national efforts outlined in the Agency's July 29th letter to MCEA equally apply to Florida. Additionally, in the EPA's own words, "Florida has developed and implemented some of the most progressive nutrient management strategies in the Nation."

Recognizing this good work in our state, on April 22nd, Secretary Vineyard of the Florida Department of Environmental Protection formally requested that EPA withdraw its Federal nutrient rules and instead allow Florida to manage nutrient loadings in its own waters. EPA has declined to accept this request, despite the clear evidence that Florida has been a national leader in water quality management. The state has invested millions of dollars into the EPA-approved TMDL program and has seen remarkable water quality improvements because of its work. In singling out Florida for federal nutrient criteria promulgation, however, EPA has continued to ignore the effective steps Florida has taken to manage nutrient loadings to its state waters.

Given your Agency's recent response to MCEA's petition and the efforts taken by our state agencies to properly implement nutrient control programs, we question the EPA's justification for ignoring the work in the State of Florida by declining to respond to the petition filed by the state on April 22nd. While we recognize the geographical differences in setting criteria for a region versus a single state, we fail to see the need for the Agency to continue to intervene in the State of Florida for the very reasons that the Agency denied MCEA's petition – the issue is best addressed by the states in cooperation with the EPA. The current regulatory scheme in Florida simply does not reflect cooperation. Furthermore and most importantly, it is our understanding that, by declining to simply take action on the DEP petition, the EPA has created further regulatory uncertainty for many of the employers in Florida eager to create more jobs for our constituents.

Consistent with the cooperative federalism envisioned by Congress in the Clean Water Act, we ask that the EPA immediately withdraw its decision to impose numeric nutrient criteria in Florida and place our state on a level playing field with states in the Mississippi River watershed and throughout the rest of the nation. Specifically, and to this end, we respectfully request that you immediately grant the petition filed on April 22nd by the State of Florida so that the state can move forward in protecting Florida's waters and businesses can move forward in creating more jobs in our state with newfound regulatory certainty.

Given the importance of this issue and the vast economic implications of inaction, we look forward to your prompt response.

Respectfully,

[illegible] Connie Mack

Bill Posey [illegible]

[illegible] [illegible]

Vern Buchanan Sandy Adams

Mosaic

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October 3, 2011

The Honorable James Inhofe, Ranking Member
Senate Environment and Public Works Committee
410 Dirksen Senate Office Building
U.S. Senate
Washington, D.C. 20515-6115

Re: U.S. Environmental Protection Agency Numeric Nutrient Rule, 40 C.F.R. § 131.43

Dear Senator Inhofe:

I am writing on behalf of the Mosaic Company ("Mosaic"), the world's leading producer and marketer of concentrated phosphate and potash, two of the primary nutrients required to grow the food the world needs. Our business engages in every phase of crop nutrition development, from the mining of resources to the production of crop nutrients, feed and industrial products for customers around the globe. Mosaic is proud to play a critically important role in the U.S. agricultural sector and in feeding the world's population. Our customer base includes wholesalers, retail dealers and individual growers in more than 40 countries. Headquartered in Plymouth, Minnesota, Mosaic employs approximately 7,400 people in eight countries. Our annual net sales are almost $10 billion and we provide tens of thousands of jobs directly and indirectly in the United States. More than half of our sales last year were tied to the phosphate rock the company mines from the 300,000 acres of land it owns in Central Florida.

Mosaic is committed to protecting the environment and working to strike a balance between meeting the growing need for food throughout the world and preserving the ecosystems around us. Our environmental focus informs every aspect of our business planning and operations. When selecting areas for mining and manufacturing, we utilize land that has been used for agriculture and other industries, leaving undisturbed wilderness untouched. We continuously evaluate our processes and explore new opportunities to practice sound environmental stewardship of our environment.

Mosaic supports sound policies and regulations to address potential nutrient impacts on the environment. We were actively involved in EPA's rulemaking entitled Water Quality Standards for the State of Florida's Lakes and Flowing Waters, 75 Fed. Reg. 75,762 (Dec. 6, 2010) ("the Nutrient Rule" or "the Rule") and we are continuing to work with EPA on the implementation of the Rule. We now write to add our voice to the many who are expressing concern regarding the Nutrient Rule and to urge you to continue your engagement and exercise of appropriate oversight over EPA on this issue. We understand the Senate Environment and Public Works Committee is holding a hearing to examine nutrient issues. As you move forward with crafting national policy addressing nutrient impacts on the environment, we respectfully request that you consider the following concerns regarding the Nutrient Rule.

Mosaic is concerned that the Nutrient Rule was not based on sound science and that EPA did not conduct a proper cost-benefit analysis in support of the Rule. As a result, the Nutrient Rule will impose substantial and unnecessary economic burdens on the State of Florida, without providing any concomitant benefits in environmental protection. For these reasons, and others, we believe that EPA's implementation of the Nutrient Rule, and its additional forthcoming rulemaking that will set numeric nutrient criteria for Florida's estuaries and coastal waters, merits serious oversight and careful review by Congress.

<u>The Nutrient Rule is Not Based on Sound Science</u>

The Federal Clean Water Act requires that water quality criteria be based on sound science. *See* 40 C.F.R. § 131.11(a)(1). However, the Nutrient Rule is riddled with scientific flaws. The criteria for total phosphorus and total nitrogen established by the Rule for Florida's streams were not, according to EPA's own statements, derived from a demonstrated relationship between a specific level of nutrients and a concrete or measureable biological or ecological effect in a receiving water. *See* 75 Fed. Reg. 4,174, 4,194 (Jan. 26. 2010) ("EPA was not able to demonstrate a sufficiently strong correlation between the biological response indicators . . . and [nutrient] concentrations.") Rather, EPA identified a suspect population of streams it considered unimpaired by nutrients, generated a distribution of nutrient values associated with these "reference" streams, and established regulatory criteria based on an EPA-selected percentile from this distribution (90^{th} percentile for most regions; 75^{th} percentile for one region). EPA's criteria are not based on any scientific evidence that nutrient levels above the criteria will, in fact, cause biological harm, <u>or</u> that nutrients below these levels will be protective of biological conditions in any particular waterbody. Furthermore, EPA's unscientific method <u>by definition</u> mandates that numerous streams that EPA itself determined to be biologically healthy will now paradoxically be deemed "impaired" under this framework.

EPA acknowledges that numerous site or location specific factors dramatically affect the relationship between nutrient levels and adverse biological impacts in any given water body, including velocity of the stream flow, the shade cover of the stream and the degree of scouring of stream substrate. *See* 75 Fed. Reg. at 4,192. Yet EPA did not take account or adjust for any of these factors in setting stream criteria, stating, with admirable candor, that it did not do so in order to avoid "the substantial expenditure of time and scarce public resources to document and interpret inevitable and expected stream variability on a site-by-site, segment-by-segment basis." *Id.*

The fatal flaws of EPA's approach were demonstrated by concrete evidence provided to EPA by numerous commenters (including Mosaic) showing that streams with nutrient criteria above the EPA criteria are nevertheless biologically healthy, and that in some areas of Florida *natural* run-off conditions have nutrient levels above the EPA criteria. *See* Mosaic Comments of April 23, 2010, pages 23-26 and Attachment 2 (EPA-HQ-OW-2009-0596-1217.2 and 1217.5). These data demonstrate empirically that EPA's criteria do not correspond to the actual conditions of Florida's waters. Accordingly, the Nutrient Rule is not based on sound scientific principles and EPA's implementation of the Rule, as well as its further rulemaking in this area, merits close review and oversight by Congress.

The Nutrient Rule Did Not Use a Valid Cost Benefit Analysis

EPA estimates the potential annual cost of the Nutrient Rule as ranging between $16.4 million and $25.3 million. 75 Fed. Reg. at 75,793. EPA's cost estimate is flawed in numerous respects; we identify only a few of the most glaring flaws here. First, EPA's estimate assumes that a potential State regulation on nutrients, never proposed or implemented by the Florida Department of Environmental Protection ("FDEP") was in effect in Florida; on that basis, EPA assessed only the *incremental* cost of the Nutrient Rule beyond the costs of the theoretical FDEP rule. (EPA's own figures suggest that an estimate of the impact of the Nutrient Rule *without* regard to the theoretical, non-existent FDEP rule would be an order of magnitude higher, ranging from $135 million to $206 million annually. *Id.*)

Second, EPA assumes that where municipal waste water treatment plants or other facilities are unable to meet the nutrient criteria, expensive investment in costly reverse osmosis or other capital intensive technology will not be necessary because "it is reasonable to assume that entities would first seek out other available means of attaining water quality standards such as reuse, nonpoint source reductions, site-specific alternative criteria, variances, and designated use modifications." *Id.* at 75,794. This analysis, by presuming that entities with costly compliance needs will simply obtain relief, "assumes away the question." Nothing in the Rule suggests or guarantees such a result.

Third, EPA does not appear to quantify the impact of the Rule on waters already considered impaired under Florida law. While EPA acknowledged that there may be costs associated with achieving nutrient reductions beyond those already contemplated, it did not quantify these costs at all. *See id.* at 75,793.

Fourth, the EPA cost estimate does not address the very substantial costs to regulated parties of seeking to avail themselves of the regulatory relief mechanisms that EPA presumes will be necessary to enable compliance with the Rule. EPA acknowledges that the Rule will require development of new or revised Total Mass Daily Loads, Site Specific Alternative Criteria, Use Attainability Analyses and applications for variances. The costs to regulated entities of seeking these relief mechanisms -- e.g., data collection, analytical work, advocacy and scientific submissions, etc. -- are not included in EPA's cost estimate.

Studies prepared by other parties and submitted to EPA project cost impacts of the Rule that far exceeds EPA's flawed estimates. For example, one study found the cost impacts of EPA's proposed Rule on the Florida phosphate industry alone to be about $1.6 billion in capital expenses and $59 million in annual operating expenses. This estimate did not include the costs of treatment of reclaimed mining lakes and streams, and other anticipated costs. The Florida Water Environmental Association estimated the costs of Rule compliance for municipal wastewater treatment plants alone to be $2.0 to $4.4 billion per year. The Florida Department of Environmental Protection estimated the compliance costs for industrial dischargers to be approximately $2.1 billion per year, and for urban storm water controls to be nearly $2 billion per year. The Florida Department of Agriculture and Consumer Services estimated the cost impact to agriculture at between $0.9 billion and $1.6 billion per year. These multiple, independent estimates provide a clearer picture of the actual impacts to Florida of this unsound regulation and demonstrate the need for Congressional oversight.

Finally, EPA's estimate of the anticipated benefits of the Nutrient Rule is equally suspect. EPA's benefit analysis assumes that the Rule will lead to improved water quality and improved ecological function in Florida's flowing waters. *See* 75 Fed. Reg. at 75,802. However, as discussed above, the scientific and methodological flaws in the Rule mean that the new criteria will not necessarily achieve any or all of the projected improvements in Florida water quality. The Rule will identify certain healthy streams as impaired -- meaning there is no benefit to be realized. It will identify other streams as impaired for nutrients when nutrients are not the cause of the impairment. And the Rule will fail to ensure that actual instances of nutrient impairment will be corrected by meeting these criteria. Consequently, EPA's assumptions regarding water quality improvements, and its resulting estimate of the benefits resulting from these alleged improvements, are ill-founded and cannot justify the costs and consequences of the Rule.

Thank you very much for your leadership on this issue. If you have questions or wish to discuss these issues further, please feel free to call me at 813-500-6486.

Sincerely,

James K. Voyles,
Director of U.S. Environmental Affairs

September 17, 2010

The Honorable Lisa Jackson
Administrator
United States Environmental Protection Agency
1200 Pennsylvania Avenue, NW
Washington, DC 20460

Dear Administrator Jackson,

The undersigned organizations are profoundly concerned with the Clean Water Act numeric nutrient criteria (NNC) policies that are now being advanced by the Environmental Protection Agency (EPA) across the U.S., and in their most prominent and current form in Florida. It is apparent that EPA's development of NNC in Florida will establish a template for how NNC should be structured nationwide. The work underway in Florida is a result of a settlement agreement with activists, which is not only highly problematic but also raises fundamental questions of fairness and transparency, and effectively undermines the rights of the regulated community to customary, open proceedings.

We strongly urge EPA to:

- Delay further NNC policymaking until it has engaged with <u>all</u> relevant stakeholders in a thorough and transparent review of the strategic direction of NNC policies.
- Revisit and update the 1998 "National Strategy for the Development of Regional Nutrient Criteria" (National Strategy).
- Not finish the NNC for Florida's lakes and streams this fall and instead work on those in concert with the NNC that EPA is planning to finalize in August 2012 for all other Florida waters – and in the process answer the numerous and significant scientific, economic and policy questions about these NNC in an open and transparent manner.
- Reject policymaking by settlement agreement, with its inherent opaqueness and the distrust that creates.

We believe that revisiting and updating the 1998 National Strategy is warranted for at least four reasons. First, during the 12 years since the strategy was issued a considerable body of applied scientific knowledge and policy experience has been developed by the research community, states, and EPA. We estimate that more than 40 states have explored how they might create NNC. We understand that this work at the state-level has involved considerable debate on substantive matters within states, between states, and between EPA and the states, and that many of these debated matters remain unresolved. This substantive experience with the difficult scientific and practical pitfalls of NNC needs to be drawn upon to develop a sound path forward for NNC policies in general. In the case of Florida, there are significant questions about the statistical, modeling and biological science used by EPA. By EPA's own admission in the proposed rulemaking, there is no scientifically established correlation between these proposed NNC and the desired biological conditions in these waters. In general, we believe there is a serious lack of rigorous, generally accepted science that justifies the particular methods EPA adopted to generate these NNC in Florida.

Second, since the development of the 1998 National Strategy, there has been little or no significant or organized public participation in NNC policy development from a strategic perspective. Such an open and transparent process is essential if specific NNC being advanced by EPA and the states are to be embraced. This is certainly a far more acceptable process than letting policy be driven by settlement agreements developed behind closed doors solely with activist groups, as has been the recent case with NNC and in other important Clean Water Act policy areas.

Third, one of the most serious drawbacks of the 1998 National Strategy is that it failed to undertake any substantive analysis of the economic costs and benefits of NNC; for the regulated community, for the economy as a whole, or for the public sector that must develop and administer the NNC. In the particular case of the Florida NNC, it is very clear that adopting the wrong criteria can cause enormous economic harm – both in the direct costs to the regulated community but also for the economy as a whole. The Florida Department of Agriculture estimates that the total **initial** cost for agricultural producers to comply with the NNC for lakes, rivers and streams to be between $855 million to $3.069 billion, and the subsequent **annual** compliance costs to be $902 Million to $1.605 billion. As a result, it estimates that the size of the Florida economy will be reduced by $1.148 billion a year and that 14,545 full and part time jobs would be lost.

Not just agriculture is at risk, of course. The Florida Department of Environmental Protection estimates that the total capital cost for utilities to comply with these NNC would be $4.167 billion. The Florida Water Environment Association estimates the cost for compliance with all of the NNC that EPA has under development to be $47.6-$98.7 billion over 30 years. They also estimate that the average household utility bill will increase $673-$726 a year.

The size of these costs for Florida alone are reason enough to justify revisiting the National Strategy to ensure that a sound and responsible path forward is developed.

Lastly, with regard to the substance of the proposed NNC, EPA needs to fully consider the implications and outcomes that will result if it sets the NNC for the lakes and streams at standards that are far too stringent, impractical and unattainable for Florida and the rest of the United States. The goals of the Clean Water Act must not be set and pursued in isolation from all of the other important goals and priorities of society, including promoting vibrant, strong job-creating businesses, economically strong communities, and the productive and valuable use of the land for agricultural and other purposes.

For all these reasons, we believe it is imperative that EPA open a meaningful, working dialogue on the strategic direction of NNC policies. We believe that is best accomplished by using as a starting point the 1998 National Strategy. The dialogue must be carried out with all the relevant stakeholders in an open and transparent manner, not simply with the activist NGOs. In the particular case of the Florida NNC, given the host of legitimate economic and scientific questions and issues, we believe the NNC for lakes and streams should not be finalized this fall, and instead subjected to further scientific development and review as part of EPA's broader effort involving the NNC for the other waters of the state. This work on the Florida NNC should be carried out in parallel to the national working dialogue we have suggested.

Sincerely,

Agricultural Retailers Association
American Farm Bureau Federation
American Feed Industry Association
American Horse Council
American Meat Institute
American Soybean Association
American Sugar Alliance
CropLife America
Florida Fertilizer & Agrichemical Association
National Alliance of Forest Owners
National Association of Conservation Districts
National Association of State Departments of Agriculture
National Association of Wheat Growers
National Barley Growers Association
National Cattlemen's Beef Association
National Chicken Council
National Corn Growers Association
National Cotton Council
National Council of Farmer Cooperatives

National Farmers Union
National Milk Producers Federation
National Pork Producers Council
National Potato Council
National Sorghum Producers
National Sunflower Association
National Turkey Federation
National Water Resources Association
Southern Crop Production Association
The Fertilizer Institute
United Egg Producers
United Fresh Produce Association
U.S. Apple Association
U.S. Canola Association
U.S. Cattlemen's Association
US Rice Producers Association
Western Growers

cc: Secretary Tom Vilsack, USDA

NEIWPCC

Fostering Collaboration on Water Issues

Training Environmental Professionals

Coordinating Water Research

Educating the Public

January 3, 2011

Administrator Lisa Jackson
USEPA Headquarters
Ariel Rios Building
1200 Pennsylvania Avenue, N.W.
Mail Code: 1101A
Washington, DC 20460

Dear Administrator Jackson,

The Northeast states recognize that nutrient pollution is a significant environmental problem that impacts many waterbodies in our region and nationwide. Efforts such as the Long Island Sound and Lake Champlain TMDLs and the Massachusetts Estuaries Project provide concrete examples of our commitment to reducing nutrient inputs to our waters. We appreciate EPA's continued focus on this issue and fully support EPA Region 1's attention to how nutrient issues in the Northeast are distinct from those in other parts of the country. Furthermore, all of our states have put significant effort and resources into the process of developing numeric nutrient criteria. While we have no intention of abandoning our efforts to develop and establish these criteria, we have significant concerns with the direction EPA is now taking regarding the independent applicability of numeric nutrient criteria. The New England Interstate Water Pollution Control Commission recently represented its member states at an Office of Water briefing hosted by EPA Region 1. There, we had the opportunity to share some of our concerns with your staff, and have highlighted them for you below.

A number of Northeast states have advanced numeric nutrient criteria development to the point of initiating the rulemaking process within their state to establish these criteria as part of their Water Quality Standards. The technical approach favored by many states bases criteria on strong scientific evidence using stressor-response relationships, where nitrogen and phosphorus are the stressors and environmental indicators are the response (e.g. chlorophyll-a, Secchi disk, indices of biological health). Because the relationship between nutrients and environmental responses is based on many site-specific factors and varies from waterbody to waterbody, these responses consolidate the many site-specific factors that must be considered for efficient application of criteria, and therefore are the most appropriate indicators of a waterbody's impairment status.

Thus, both Maine and Vermont are proposing criteria for freshwater that are based on a decision framework that takes into account both causal variables (nitrogen and phosphorus) and environmental responses relevant to each waterbody. While EPA has argued that single number criteria approaches should be used, no such uniformity of condition exists in the natural world. Because nutrients are not toxic contaminants with threshold responses, conditions demonstrated by acceptable biological responses that are reflective of a range of nutrient conditions are the most appropriate way to

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apply criteria. While ambient concentrations may be helpful in screening potential impairments, under a decision framework approach, a waterbody would be considered impaired only if one or more measured environmental response criteria did not meet limits, regardless of whether or not the established phosphorus or nitrogen criteria were exceeded. In the case that all measured environmental response criteria are met, the waterbody would not be considered impaired, even if nitrogen or phosphorus concentrations were above the state's numeric criteria.

Based on the final criteria established by EPA for the state of Florida, and feedback provided to the states of Maine and Vermont by EPA Region 1, EPA is not supportive of response-based approaches. EPA has taken the position that states can incorporate response variables but must include numeric nutrient criteria for both nitrogen and phosphorus and that each criterion must be independently applicable to determine a waterbody's impairment status. By taking this position, a waterbody could be determined to be in violation of water quality standards even when a biological impairment does not exist. In addition, by requiring both nitrogen and phosphorus criteria to be incorporated into state water quality standards and applied independently, technological controls could be required to remove both nutrients even though most systems are controlled by the most limiting nutrient (i.e., typically phosphorus in freshwater and nitrogen in marine waters). This added burden could result in significant increases in sludge production and treatment and energy costs, despite not being necessary to control eutrophication in most cases. We recognize that there are some POTWs that discharge to both freshwater and marine systems, but this is the exception and not the rule.

EPA Region 1 has recently suggested a framework that allows for a waterbody exceeding a numeric criterion but meeting acceptable levels for environmental response variables to be listed as "indeterminate" for its attainment status. We appreciate the Region's continued dedication to finding a solution that is workable for both parties, but we still have the same fundamental objection that a waterbody that is meeting environmental response criteria should be listed as attaining standards even if it exceeds a numeric nutrient criterion. We understand that EPA has concerns about implementing response-based criteria, but we feel that this is a question that is dealt with in permitting, not standards development. Further, the Northeast states have solid experience in crafting defensible and robust permits with effluent limits derived from these same response-based criteria. We are committed to working with both of our EPA regions to continue implementing these valid and defensible limits using already endorsed EPA methodologies.

In summary, the Northeast states believe that EPA has failed to produce sufficient scientific evidence or a viable legal or policy basis for the imposition of independent applicability of numeric nutrient criteria. In addition, the Northeast states do not agree that numeric criteria for both nitrogen and phosphorus are necessary for all waterbodies. Numeric criteria should only be required for the limiting nutrient in a system unless dual limitation is demonstrated.

The Northeast states have amply demonstrated that using environmental response variables to develop nutrient criteria is a scientifically valid approach that is highly protective of water quality. Many years of data collection and analysis have gone into development of these criteria. Furthermore, in their review of EPA's *Technical Guidance on Empirical Approaches for Numeric Nutrient Criteria Development*, EPA's Scientific Advisory Board (SAB) recognized that a stressor-response approach is a legitimate, scientifically-based method for developing numeric nutrient criteria when it is applied appropriately, such as part of a tiered weight-of-evidence approach. The approaches being proposed by the Northeast states fall in line with this recommendation by the SAB, especially with respect to the potential range of acceptable nutrient concentrations, and their site-specificity, that a weight-of-evidence approach supports.

The Northeast states are very appreciative of the assistance provided by EPA Region 1 throughout the nutrient criteria development process and have every intention of continuing the scientific work that will build the foundation of their numeric nutrient criteria. We also plan to continue to address nutrient impairments through NPDES permitting, TMDLs, and adaptive watershed management, while criteria are being developed and put in place. However, the Northeast states are concerned about EPA's approach, and many states are taking the position that they will not proceed any further with adoption of numeric nutrient criteria until EPA has provided sufficient explanation of the legal requirement and scientific basis for the requirement for independent applicability of criteria. Once those concerns can be addressed, we will renew our commitment to the process of establishing these important criteria in earnest.

Thank you for your consideration of the concerns we have described. We are eager to continue working with you on this important environmental issue and look forward to your response.

Sincerely,

Ronald Poltak
Executive Director

Cc: Curt Spalding, Regional Administrator, EPA Region 1
Judith Enck, Regional Administrator, EPA Region 2
NEIWPCC Executive Committee

ALFA FARMERS

JERRY A. NEWBY
PRESIDENT

September 29, 2011

The Honorable Jeff Sessions
United States Senate
326 Russell Senate Office Building
Washington, DC 20510

RE: Subcommittee on Water and Wildlife Hearing Entitled "Nutrient Pollution: An Overview of Nutrient Reduction Approaches" – Hearing on October 4, 2011

Dear Senator Sessions:

Alabama farmers are more concerned today than ever before about the future of agriculture, not only because of volatile markets, global competition, or even unpredictable weather patterns, but because of the continued onslaught of regulations, rules, and guidance documents brought forth by the Environmental Protection Agency (EPA). While farmers, possibly more so than any other segment of the population, understand the importance of a healthy ecosystem and clean water, they continue to be singled out by federal agencies and environmental groups. However, the reality is that farmers are continuing to implement production practices that allow them to be better environmental stewards, resulting in far less environmental impacts than ever before.

From no-tillage production systems on row crop operations, to nutrient management plans on poultry farms, today's farmers are doing their fair share to ensure the next generation has necessary resources available to feed and clothe the world's increasing population. These resources certainly include clean water, clean air, and fertile lands, all of which are important to agricultural production. A growing number of farmers also employ Global Positioning System (GPS) technology to more closely control the inputs, including fertilizer, that are used in the production of a crop. This technology greatly reduces the potential for runoff of excess nutrients or pesticides. Additionally, productivity on a per acre and per animal basis is higher than ever before, meaning for every acre harvested or every cow milked, more bushels of corn and more gallons of milk are produced with fewer inputs. This results in less waste and a decreased environmental impact. With the high cost of nearly every agricultural input from fuel to fertilizer, it only makes sense for farmers to continue to strive to further reduce inputs such as fertilizer, thereby reducing nutrient runoff.

One example of the current Administration and EPA taking aim at farmers in an unprecedented manner is the Chesapeake Bay TMDL. Ignoring the substantial effort and progress made by the agricultural community and others in recent years, the EPA moved forward with an aggressive and inflexible new plan to regulate farming practices in the Chesapeake Bay watershed. In the last two years, EPA has set in motion a significant number of new regulations that will fundamentally alter the face of agriculture nationwide. In fact, the EPA has even touted the Chesapeake Bay TMDL as a potential model program for other watersheds across the country, and it appears the Mississippi River Basin could be targeted next in light of the EPA's signed agreement with a contractor to develop a system of total maximum daily loads (TMDL) for the region as a way to reduce the hypoxic zone in the Gulf of Mexico.

In another troubling move, the EPA finalized water quality standards for the State of Florida, known as numeric nutrient criteria. Numeric nutrient criteria are quantitative water quality standards that will apply only to the State of Florida. By imposing a unilateral federal regulation, EPA is essentially undoing the positive efforts already underway by the state agencies that are most familiar with Florida's unique needs. As Alabama farmers observe these steps taken by EPA to our neighbors in Florida, and continue to hear rumblings about federally developed TMDLs to the west in the Mississippi River Basin, we cannot help but be alarmed.

While one should never discount the value of a healthy environment from an ecological perspective, we must also consider the health of our nation's economic environment. Just as measures are implemented to require certain biological and chemical parameters that allow organisms to flourish and reproduce, we must also implement sensible economic and regulatory policies to allow for the prosperity and growth of the agricultural sector of rural America. At a time when jobs are needed to stimulate the economy, and world markets are primed to allow for more agricultural exports than ever before, it seems counterintuitive to hinder the productivity of the American farmer. Common sense and sound science should be used as the basis for the promulgation of new environmental regulations, and they should only be enacted when environmental gains can be justified in light of economic consequences.

With the progress already made by production agriculture in regards to environmental stewardship, much of it voluntarily, it seems that EPA would be interested in recognizing the great strides farmers have made, rather than continuing to find ways to make their already difficult job more burdensome. We respectfully ask the members of this subcommittee to encourage the EPA and other federal agencies to identify ways to address nutrient management issues in a transparent, productive manner as opposed to the rigid, unilateral approach that has been the case in recent months. Furthermore, we humbly request continued oversight of rules and regulations related to nutrient management programs to assure they are based on sound, objective science, and thoroughly evaluated for economic impacts to agriculture and rural America.

Sincerely,

Jerry A. Newby

Jerry A. Newby
President

/mh

BLUEGREEN
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Minneapolis, MN 55414

1020 19th Street NW, Suite 600
Washington, D.C. 20036

330 Townsend Street, Suite 205
San Francisco, CA 94107

October 2, 2011

Senator Ben Cardin
Chairman, Subcommittee on Water and Wildlife
Senate Environment and Public Works Committee
509 Hart Senate Office Building
Washington, DC 20510

Dear Senator Cardin,

The BlueGreen Alliance – a partnership of 10 of the nation's largest labor unions and 4 of America's most influential environmental organizations, representing more than 14 million members and supporters united in working toward a clean energy economy – see the ecological and public health benefits of clean water as sacrosanct. We also see efforts to provide clean drinking water, conserve water and protect our nation's waterways as integral in job creation and supporting a strong domestic economy.

Environmental regulations, such as the Clean Water Act, produce jobs in several ways. They encourage the development of advanced technology and promote competition to comply with needed standards. In many cases, industrial and agricultural processes that produce significant amounts of pollution are inefficient, and improving them sparks new approaches that increase productivity and often result in new investment, which in turn preserves or create jobs.

Furthermore, they promote innovation through joint public and private efforts, for example through pilot projects that leverage academic, scientific and business resources to mitigate pollution with community, industry and government stakeholder buy-in.

Second, controlling pollution itself produces new jobs in manufacturing and operations, in implementation of new technologies and the operations and maintenance of facilities that keep pollution low.

Lastly, environmental damage entails impacts to public health, which can reduce people's ability to work effectively. Improving people's health means workers improve their productivity, earn more and spend that extra income on goods and services, creating or maintaining jobs in the larger economy.

The BlueGreen Alliance thanks you for ensuring Americans enjoy safe drinking water and clean, clear rivers and streams. We support your dedication to these issues and defense of the Clean Water Act across multiple bi-partisan efforts. Our labor and environmental partnership hopes that moving forward, the economic case for strong water standards is fully factored into progressive policies that develop robust water infrastructure, protect water resources and deliver clean, safe drinking water.

Sincerely,

David Foster
Executive Director
BlueGreen Alliance

Review of the LimnoTech Report, "Comparison of Load Estimates for Cultivated Cropland in the Chesapeake Bay Watershed"

A report of the independent review conducted by the
Chesapeake Bay Program's
Scientific and Technical Advisory Committee

And prepared by the
Committee for the ANPC/LimnoTech Review

September 26, 2011

STAC Publication 11-02

This report was prepared for the Chesapeake Bay Partnership by an independent review committee organized by the Scientific and Technical Advisory Committee (STAC) of the Chesapeake Bay Program. The Committee for the ANPC/LimnoTech Review consisted of four external reviewers and six STAC members on the review steering committee:

External Reviewers

Richard B. Alexander, Research Hydrologist, U.S. Geological Survey, Reston, Virginia
Theo A. Dillaha, Professor of Biological Systems Engineering, Virginia Tech
Christopher J. Duffy, Professor of Civil Engineering, Department of Civil and Environmental Engineering, The Pennsylvania State University, University Park, Pennsylvania
Adel Shirmohammadi, Professor of Environmental Science and Technology, College of Agriculture and Natural Resources Associate Dean for Research, Associate Director of the Maryland Agricultural Experiment Station, and Affiliate Professor of Fishell Department of Bioengineering , University of Maryland

STAC Steering Committee Members

Russell B. Brinsfield, Research Associate & Center Director, Wye Research and Education Center, University of Maryland, Queenstown, Maryland
Marjy Friedrichs, Associate Professor of Marine Science, Virginia Institute of Marine Science, Gloucester Point, Virginia.
Robert M. Hirsch, Research Hydrologist, U. S. Geological Survey, Reston, Virginia
Michael Paolisso, Associate Professor, Department of Anthropology, University of Maryland, College Park, Maryland.
Donald E. Weller, Senior Scientist, Smithsonian Environmental Research Center, Edgewater, Maryland
Eugene R. Yagow, Senior Research Scientist, Biological Systems Engineering Department, Virginia Tech

The review committee thanks the lead developers of the two watershed models considered here
M. Lee Norfleet, Soil Scientist, USDA Natural Resources Conservation Service, Resources Inventory and Assessment Division, Texas AgriLife Blackland Research and Extension Center, Temple, Texas
Gary Shenk, Integrated Analysis Coordinator, USEPA Chesapeake Bay Program Office, Annapolis, Maryland
Norfleet and Shenk met with the review committee to provide information and answer questions about their models.

The review committee also thanks STAC staff members Matthew Johnston and Natalie Gardner for their help in organizing and accomplishing the review.

About the Scientific and Technical Advisory Committee

The Scientific and Technical Advisory Committee (STAC) provides scientific and technical guidance to the Chesapeake Bay Program on measures to restore and protect the Chesapeake Bay. As an advisory committee, STAC reports periodically to the Implementation Committee and annually to the Executive Council. Since its creation in December 1984, STAC has worked to enhance scientific communication and outreach throughout the Chesapeake Bay watershed and beyond. STAC provides scientific and technical advice in various ways, including (1) technical reports and papers, (2) discussion groups, (3) assistance in organizing merit reviews of CBP programs and projects, (4) technical conferences and workshops, and (5) service by STAC members on CBP subcommittees and workgroups. In addition, STAC has the mechanisms in place that will allow STAC to hold meetings, workshops, and reviews in rapid response to CBP subcommittee and workgroup requests for scientific and technical input. This will allow STAC to provide the CBP subcommittees and workgroups with information and support needed as specific issues arise while working towards meeting the goals outlined in the Chesapeake 2000 agreement. STAC also acts proactively to bring the most recent scientific information to the Bay Program and its partners. For additional information about STAC, please visit the STAC website at www.chesapeake.org/stac.

Publication Date:
September 23, 2011

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11-02

STAC Administrative Support Provided by:
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Table of Contents

Executive Summary

The LimnoTech/ANPC report *Comparison of load estimates for cultivated cropland in the Chesapeake Bay watershed* analyzed the results of two Chesapeake watershed modeling efforts. The models were the Chesapeake Bay Program's watershed model (the CBP model, which was developed to evaluate actions needed to meet TMDL requirements) and a recently published USDA-NRCS model (CB-CEAP model) developed to quantify the effects of conservation practices applied to cultivated cropland in the Chesapeake Bay watershed. LimnoTech is the consulting firm that prepared the report for its client, the Agricultural Nutrient Policy Council (ANPC), an interest group representing several agricultural trade organizations.

LimnoTech reported differences between the CBP and CB-CEAP models and their results, and then recommended suspending implementation of the Chesapeake Bay TMDL until the differences were resolved.

The Chesapeake Bay Partnership asked the Scientific and Technical Advisory Committee (STAC, an advisory board for the Chesapeake Bay Partnership) to convene an independent, expert panel to review the LimnoTech report and to make recommendations concerning the application of multiple models in environmental management of the Chesapeake Bay. This report presents the findings of the review committee.

The committee concludes that the LimnoTech analyses have poor scientific merit and promote a false set of criteria by which to judge the suitability of the CBP watershed model for use in the TMDL implementation process. LimnoTech based its recommendations on unrealistic criteria for watershed model performance, inappropriate expectations for agreement between watershed models developed for different objectives, selective interpretation of the findings of the CB-CEAP report, and errors in the interpretation of the models and their results. LimnoTech failed to acknowledge that fundamental differences in models (such as the input data, assumptions, and process representations) are unavoidable because of the different objectives of the models and differences in the data and resources available to support each effort. LimnoTech's analysis also ignores the appreciable differences between the models in purpose, history, extent of calibration, extent of validation with independent data, level of spatial discretization, and degree of stakeholder involvement in model scenario development--differences that favor the continued use of the CBP model to inform and guide the implementation of management actions to meet TMDL requirements.

When LimnoTech's errors in interpretation of model results are corrected, the results of the two models are more similar to each other than reported by LimnoTech. The corrected results indicate that the model predictions of loads are in approximate agreement despite the differences in model objectives, assumptions, input data, model frameworks, and spatial and temporal details. More importantly, the results of the two models are similar in their assessment of the need for implementing more management practices on cropland.

The CB-CEAP model and its supporting data provide new knowledge and approaches that can inform and improve the CBP model and its application to watershed management planning. The review committee commends the ongoing efforts between the CBP and USDA to compare and integrate their data and analyses, and the committee recommends many other activities that could enhance the application of multiple models in managing nutrient and sediment pollution of the Chesapeake Bay (see section on Recommendations for Integrating Models).

In summary, the review committee finds that LimnoTech's comparison of the CBP and CB-CEAP models is flawed and does not provide sufficient evidence to suspend implementation of the Chesapeake Bay TMDL.

Introduction

The LimnoTech/ANPC report (LimnoTech 2010, 2011) compared the results of two watershed modeling efforts. One effort used the Chesapeake Bay Program's Chesapeake Bay Watershed Model (hereafter called the CBP model, USEPA 2010a), which has been developed and applied to plan the watershed management actions that will be needed to meet the requirements of the Chesapeake Bay TMDL (Total Maximum Daily Load, USEPA 2010b). The second modeling effort (hereafter called the CB-CEAP model), used a suite of USDA-ARS (Agricultural Research Service) models (APEX and HUMUS/SWAT). The CB-CEAP model incorporated data from the USDA-NRCS (Natural Resources Conservation Service) National Resource Inventory (NRI) and farmer surveys from the Conservation Effects Assessment Program (CEAP) to quantify the effects of conservation practices applied to cropland in the Chesapeake Bay watershed (USDA-NRCS 2010, 2011). LimnoTech is an environmental and engineering consulting firm that prepared the report for its client, the Agricultural Nutrient Policy Council. ANPC is an interest group whose steering committee includes members of the following organizations: Agribusiness Retailers Association, the American Farm Bureau Federation, The Fertilizer Institute, the National Corn Growers Association, the National Council of Farmers Cooperatives, and the National Pork Producers Council. The LimnoTech report and its revision are contracted products delivered to a client (ANPC), not peer reviewed scientific reports.

LimnoTech observed some differences between the CBP and CB-CEAP models and their results, and then recommended suspending implementation of the Chesapeake Bay TMDL until the noted differences can be resolved (LimnoTech 2010, 2011). LimnoTech's report has been cited in the popular press, congressional testimony, and entered into evidence in lawsuits seeking to stop the implementation of TMDL requirements.

In March 2011, the Chesapeake Bay Partnership asked the Scientific and Technical Advisory Committee (STAC), an independent advisory board for the Chesapeake Bay Partnership, to convene an independent, external review panel to evaluate the LimnoTech report. The review panel was asked to address the following questions:

1. Are the LimnoTech analyses and recommendations based on reasonable expectations for watershed models and expected differences between models?
2. Does LimnoTech accurately represent the two models and their results (is the report factually correct)?
3. What future activities could be undertaken by CBP, USDA, STAC, or other interested parties to improve the application of multiple models to environmental management and regulation in the Chesapeake Bay watershed?

This report presents the findings and recommendations of the review committee. Key findings are presented in bold type throughout the text.

Realistic Expectations for Watershed Models and Agreement between Models

Apart from the specific characteristics and results of the CBP and CB-CEAP models that LimnoTech considered, their report highlights a broader issue of how alternative models should be used to inform but not derail the implementation of TMDL requirements. Unfortunately, some of the statements in the LimnoTech report are based on misinterpretation of what watershed models can do and how closely alternative models that are developed and implemented for different objectives should agree. The following section presents some basic information about watershed modeling (and models in general) to provide more realistic expectations for model comparisons for use in evaluating the LimnoTech report and in future model comparison analysis. The use of models in environmental decision making is not new. The basic principles we summarize here were more completely developed by a panel of the National Research Council of the National Academies (Box 1).

Box 1. National Research Council findings on models in environmental decision making.
The National Research Council (NRC) is a neutral non-governmental scientific body chartered to provide expert scientific advice to the Federal Government. Some highly relevant findings from their report *Models in Environmental Regulatory Decision Making* (NRC 2007) are quoted below:

Models will always be constrained by computational limitations, assumptions, and knowledge gaps. They can best be viewed as tools to help inform decisions rather than as machines to generate truth or make decisions. Scientific advances will never make it possible to build a perfect model that accounts for every aspect of reality or to prove that a given model is correct in all respects for a particular regulatory application. These characteristics make evaluation of a regulatory model more complex than solely a comparison of measurement data with model results. They suggest that model evaluation be viewed as an integral and ongoing part of the life cycle of a model, from problem formulation and model conceptualization to the development and application of a computational tool.

Models have a long history of helping to explain scientific phenomena and of predicting outcomes and behavior in settings where empirical observations are limited or not available. The use of models has resulted in great advances in scientific understanding and in improvements in a wide array of endeavors. However, by their very nature, all models are simplifications and approximations of the real world. Complex relationships are often simplified, and relationships viewed as unimportant are sometimes eliminated from consideration to reduce computational difficulties and increase transparency.

Models are always incomplete, and efforts to make them more complete can be problematic. As features and capabilities are added to a model, the cumulative effect on model performance needs to be evaluated carefully. Increasing the complexity of models without adequate consideration can introduce more model parameters with uncertain values, and decrease the potential for a model to be transparent and accessible to users and reviewers. It is often preferable to omit capabilities that do not improve model performance substantially. Even more problematic are models that accrue substantial uncertainties because they contain more parameters than can be estimated or calibrated with available observations.

Watershed models are essential tools for developing and implementing TMDL requirements. For TMDLs based on nutrient and sediment loadings, models are needed to estimate acceptable loads, quantify all relevant sources, and identify strategies that can be expected to lead to the desired load reductions. Because of the complexity of the many physical, chemical, and biological processes on the land and in the waters and because of the multitude of land-uses and point sources distributed across a large and diverse watershed, the only way to integrate the information is through the use of a watershed model that can integrate all of the relevant data and process descriptions. In order for the model to be useful to the TMDL process, the model's output must be compared with monitoring data at a large number of locations in the watershed to determine if it provides a reasonable approximation of the actual status and trends of water quality in the watershed and to better understand the uncertainties associated with the model's predictions. It must use validation[1] periods that were not used in model calibration in order to develop confidence in its ability to provide useful estimates of the water-quality outcomes of likely and proposed future changes in the watershed.

Despite their critical importance in watershed management, models are imperfect. The best models are only approximations of the real world. Model complexity is limited by computer power, input data requirements, data availability, and by the tendency for additional model complexity to increase model uncertainty. Sources of data about landscape and river characteristics all have limits of accuracy and spatial resolution, and the same is true for representations of human activities on the watershed (not only for agriculture but also for urban and industrial activities). Key data to properly represent important processes are often unavailable. It is not possible to include all the relevant processes and information in a model, and more complex representations of processes do not necessarily improve a model, particularly when the data to estimate key parameters are lacking (Box 1).

The practical limits on model complexity and available data require that modelers focus on factors important to model objectives and deemphasize or eliminate less important complexities. The choices are driven by model objectives, available data, and available modeling resources. Simplifications and approximations are a necessary and appropriate aspect of models (Box 1). It is inevitable that models with different objectives and resources will use different frameworks, make different simplifying assumptions, operate on different time scales, rely on different inputs, and produce different outputs. The resulting diversity in modeling approaches is scientifically valuable because the range of outcomes from multiple models provides a first order indication of the uncertainty in model predictions. This information can guide future model development to reduce uncertainty. When model predictions are used in making management decisions, the range of outcomes can help quantify appropriate margins of safety that account for the uncertainty in model results.

In contrast to the wisdom of the NRC experts (Box 1) and the basic principles summarized above, LimnoTech's recommendations are built upon false expectations for watershed models. Given that no model can be complete or perfect, LimnoTech's (2010, 2011) admonition to ensure that the CBP model is "correct" before proceeding with implementing the TMDL is a false expectation. Models cannot be "correct", but they can be reasonable and useful for their objectives. For water quality management models, reasonableness can only be judged by evaluation of the conceptual underpinnings of the model, the input data, and demonstration of the ability to simulate approximate water-quality conditions and changes in those conditions at watershed scale.

LimnoTech's (2010, 2011) demand that all the differences in assumptions, input data, model frameworks, time scale, etc. between the CBP and CB-CEAP models should be resolved before TMDL implementation can proceed is again a false expectation. Both of the models examined by LimnoTech are intended to determine relative impacts of different land uses and land management practices under varying climatic conditions over time. However, each has its

[1] Throughout the report we use the term "validation" to represent the activity of testing a model's ability to predict observed flow or water quality data that have not already been used in model development or calibration.

specific objectives, so the two models use different mathematical algorithms and require different input data to achieve their intended goals. A CB-CEAP model effort with the same level of effort that has been used in developing, calibrating, and evaluating the CBP model would likely take years and require hundreds of thousands to millions of dollars of additional investment that we believe could be better spent in implementing the TMDL and adaptively assessing water quality responses to implementation.

LimnoTech states that the CBP model and the EPA require "the TMDL to be accurate to a single pound." Measures of uncertainty are intrinsically reflected in the margin of safety for the TMDL, and thus imprecision is acknowledged to be present both in the models and in the statement of the TMDL. It is unclear where LimnoTech obtained the notion that the EPA expects TMDLs to be accurate to a single pound because no TMDL has or will ever likely obtain such accuracy, and most watershed modelers would concur that such a goal is folly.

Based on our review, the committee finds that the LimnoTech analyses and recommendations promote a false set of criteria by which to judge the suitability of the CBP watershed model for use in the TMDL development and implementation processes. LimnoTech's recommendations are based on false expectations about the capabilities of watershed models and how much agreement should be expected among alternative models built to accomplish different objectives as well as a misunderstanding of the role that models play in informing the TMDL development and implementation.

A major concern of the review committee is that LimnoTech failed to recognize that fundamental differences in models, (such as the input data, assumptions, and process representations) are unavoidable because of the different objectives of the models and differences in the data and resources available to support each effort. The development of multiple modeling approaches in the Chesapeake Bay watershed reflects a natural evolution of the watershed science and management activities in the region. This is entirely appropriate and can be beneficial to the TMDL process over the long term. The existence of multiple models does not impugn the utility or validity of the individual models for their intended purposes. The separate CB-CEAP and CBP modeling efforts represent an opportunity to enhance the CB modeling framework and the TMDL development and implementation processes through collaborative evaluations and further development of the models by the EPA and USDA. However, **the review committee finds that the existence of differences in the models and model predictions provides an insufficient basis for suspending the existing TMDL implementation efforts** as called for by LimnoTech.

The review committee hopes that the general information on realistic expectations for watershed models that we have summarized here will help future model comparisons avoid misinterpretations and flawed recommendations like those offered in the LimnoTech report.

Key Characteristics of the CBP and CB-CEAP Models

The CBP and CB-CEAP models were developed for different purposes (Table 1). The developers of each model chose simplifying assumptions, model frameworks, time steps, simulation periods, and data sources that were appropriate for their specific model objectives. The two models were subjected to different levels of calibration, validation, and peer review. Key characteristics of the development and application of the two models to the Chesapeake Bay watershed are summarized in Table 1 and presented in more detail in the succeeding text.

Table 1. Overview of differences between the CBP and CB-CEAP models.

	CBP Model	CB-CEAP Model
Purpose	Quantify and improve our understanding of the contributions of all point and nonpoint source loadings of pollutants to the Chesapeake Bay with an ultimate goal of developing comprehensive strategies that can be expected to improve Chesapeake Bay water quality such that it meets agreed-upon goals.	Quantify the effects of conservation practices commonly used on cultivated cropland in the Chesapeake Bay region, evaluate the need for additional conservation treatment in the region, and estimate the potential gains that could be attained with additional conservation treatment.
History	A succession of models developed and improved over a period of 30 years, with many publications of model description and performance information over that time frame	The application of this suite of models to the Chesapeake Bay was first made available for public review in October, 2010 and in final form in February, 2011
Peer review	Components of the model have been published in the peer-reviewed literature. External scientific panels have published reviews and recommendations on the complete model system (Band et al. 2005, 2008) and the land use (Pyke et al. 2008, Pyke 2010) and BMP (Pease et al. 2007, 2008) components	Components of the model have been published in the peer-reviewed literature. Individual external reviewers examined draft versions (e. g., USDA-NRCS 2010) of the initial report on applying the complete model system to the Chesapeake Bay watershed (USDA-NRCS 2011)
Model oversight and technical team	Chesapeake Bay Partnership: USEPA, USDA, USGS, Maryland, Virginia, Interstate Commission on the Potomac River Basin, and universities	USDA and universities
Simulated time period and time step	21-year simulation period of which 10-years is used as TMDL baseline. Time step is hourly	47-year simulation period. Time step is daily
Calibration and validation[1]	Locations throughout the Chesapeake Bay watershed (237 locations for flow, 215 for total phosphorus, 200 for suspended sediment, 115 for total nitrogen, 216 for ammonium-nitrogen and 219 for nitrate-nitrogen, (USEPA 2010a, Table 11-1)	5 locations within the Chesapeake Bay watershed (Kannan et al. 2011)

[1]We use the term "validation" throughout the report to represent the activity of testing a model's ability to predict observed flow or water quality data that have not already been used in model development or calibration.

The CBP model

The current Phase 5.3 version of CBP model (USEPA 2010a) was developed over a 30-year period and the current version meets the needs of the TMDL development process. The CBP model is linked to the estuarine water quality model that is used to identify impairments in the Bay and to evaluate whether nutrient and sediment reductions from proposed management actions can remove those impairments. The CBP model has been developed by the collaboration of USEPA Chesapeake Bay Program, the U.S. Geological Survey (USGS), the Interstate Commission on the Potomac River Basin, the Maryland Department of the Environment, the Virginia Department of Conservation and Recreation, and the University of Maryland. Through an interactive and iterative process of development, testing, review, and improvement; each successive version of the model has added more detail, more process representation, better input data sets, and finer temporal and spatial representation of the watershed. Technical direction has come from several groups within the Chesapeake Bay Program structure: The Water Quality Goal Implementation Team, the Modeling Workgroup, and the Agricultural Nutrient and Sediment Reduction Workgroup, the Urban Stormwater Workgroup, the Forestry Workgroup, and the Wastewater Workgroup. The current co-chair of the Agricultural Nutrient and Sediment Reduction Workgroup works for the USDA.

The model is spatially complex and has 1185 spatial segments in the Chesapeake watershed. Those segments average 54 square miles in area. The model simulates rainfall, runoff, subsurface flows, and evaporation from landscapes including forest, agricultural and urban lands. It models soil erosion and pollutant loadings from the land to the rivers and considers the role of a wide range of BMPs in reducing these sediment and pollutant inputs. Expert panels have been convened to develop the appropriate reduction factors based on available studies. The CBP model simulates the downstream movement, deposition, and transformation of sediment and pollutants through lakes, rivers and reservoirs. These simulations use an hourly time step. The calibration period is 21 years, and simulations for TMDL analyses are run for ten years. The model produces time series of concentrations and loadings to the Bay, which are processed by the estuary model to estimate impacts on water quality and ecological outcomes in the Bay.

The model is calibrated and validated at water-quality monitoring sites throughout the basin (Table 1). A number of key parameters are adjusted in this process to improve the match between observed and predicted fluxes at these monitoring locations.

Components of the CBP model, such as the HSPF model (Hydrologic Simulation Program FORTRAN), have been the subject of many peer-reviewed publications, and the complete CBP model system has been peer reviewed by independent committees (Band et al. 2005, 2008). Independent peer reviews have also examined the land use and land cover data (Pyke et al. 2008, Pyke 2010) and the efficiency estimates of best management practices (Pease et al. 2007, 2008) used in the model.

The CB-CEAP model

The CB-CEAP model of the Chesapeake Bay watershed was developed recently as part of a nationwide effort to assess the effects on conservation practices on nutrient and sediment losses from cultivated cropland. Although the CB-CEAP model incorporates a number of agricultural and hydrologic process simulation models that have been developed over many years, the full analysis of the Chesapeake Bay watershed was first released for review in August 2010, a revised draft was released for further comment in October 2010 (USDA-NRCS 2010), and the final version was released in February 2011 (USDA-NRCS 2011). The CB-CEAP model was used to explicitly quantify the effects of conservation practices commonly used on cultivated cropland in the Chesapeake Bay region, to evaluate the need for additional conservation treatment in the region, and to estimate the potential gains that could be attained with additional conservation treatment (USDA-NRCS 2010, 2011).

The CB-CEAP effort used a suite of models to extrapolate results from field level crop surveys to the entire Chesapeake Bay watershed. Field level crop data for the years 2003-2006 were obtained at 771 NRI sample areas (averaging approximately 0.5 square mile in area) within the Chesapeake Bay watershed. Sets of unique cropland hydrologic response units (HRUs) were then aggregated within each of the four 4-digit HUCs in the Bay watershed (averaging approximately 16,000 square miles) and simulated with the APEX model. The SWAT model was then applied to the cropland HRU per-acre loads from the APEX model together with cropland distribution data and data from the HUMUS database to simulate cropland HRU loads within each of the fifty-five 8-digit HUCs in the Bay watershed (averaging approximately 1,160 square miles). The temporal resolution of the model was daily. The duration of the simulation was a 47-year period, but the baseline land use and land management conditions reflect the years 2003-2006. Soil processes were modeled in detail for agricultural lands.

Observed annual flux estimates for sediment, total phosphorus, and total nitrogen were compared with model output at five sites (three on the Susquehanna River and one each on the Potomac River and the James River).

The component parts of the model (SWAT, HUMUS, and APEX) appear in many peer reviewed publications. Drafts of the report on the integration of the component models and their application to the Chesapeake Bay watershed (USDA-NRCS 2010) were examined by individual external reviewers before the report was published in final form (USDA-NRCS 2011). We are aware of no external review publications that evaluate the application of the model to the entire Chesapeake watershed.

One major concern with comparing the CBP and CB-CEAP model results is that the sample size of the CB-CEAP survey of farmer practices on cultivated cropland is too small to allow reliable and defensible reporting of results for areas smaller than a 4-digit hydrologic unit code (HUC) subregion (USDA-NRCS 2011, page 19). There are four 4-digit HUCs (numbers 0205, 0206, 0207, and 0208) within the CB watershed with an average area of 16,000 square miles. They are the Susquehanna River Basin, the Potomac River Basin, the Upper Chesapeake Eastern and Western Shores, and the Lower Chesapeake (which includes the Rappahannock, York, and James Rivers and other minor tributaries of the lower eastern and western shores of the Bay).

Differences between the models

These brief descriptions of the CBP and CB-CEAP models reveal some important differences between the two models. The CBP model was developed specifically as a tool for understanding and managing all major sources of pollution in the Chesapeake Bay watershed. The CBP model is designed to assimilate the best available knowledge to account for nutrient or sediment sources and possible reductions in the loads from all source sectors (not just cultivated cropland). In contrast, the CB-CEAP model was developed to estimate the effects of conservation practices that were applied to cultivated cropland during the period 2003 to 2006 (USDA-NRCS 2011). Consequently, the CB-CEAP model emphasizes cropland and does have more field-scale detail for cropland than the CBP model. However, CB-CEAP contains less detail than the CBP model for other nutrient and sediment sources, and CB-CEAP does not consider BMPs for non-cropland sources.

In their report and recommendations, LimnoTech ignored differences of more than an order of magnitude in the level of discretization of subwatersheds. The CB-CEAP watershed discretization for its SWAT watershed modeling was done at the 8-digit HUC scale. There are 55 8-digit HUCs within the Chesapeake Bay watershed, so the CB-CEAP simulates the 64,000 mi^2 Chesapeake Bay watershed as 55 subwatersheds averaging 1,160 mi^2 each. In contrast, the CBP model is discretized at a much finer scale—it has 1,185 subwatersheds (river segments) averaging 54 mi^2 each. Consequently, the spatial scale for reporting the results from the CB-CEAP model is much coarser than the scale applied in the CBP model to support the TMDL allocation process. LimnoTech also ignored the differences in the calibration and validation efforts of the two modeling approaches. The CBP model was extensively calibrated and validated to stream monitoring data at locations throughout the Chesapeake watershed (Table 1) while the CB-CEAP model was only calibrated and validated at five locations in the watershed. The differences in levels of calibration and validation are significant concerns in the comparison of model output. The review committee is not criticizing the CB-CEAP effort for its level of discretization, calibration, and validation. The levels of discretization, calibration, and validation of the CB-CEAP program were appropriate for the purpose of the CB-CEAP effort. However, we are critical of LimnoTech's report and recommendations because they fail to acknowledge that the scale of information and levels of calibration and validation in the CBP model were chosen for the model's purpose in supporting the TMDL implementation effort.

The review committee finds that LimnoTech's comparison of the two modeling efforts and the resulting recommendations are unrealistic because the two modeling efforts were developed for different purposes and because the levels of hydrologic discretization, calibration, and validation differed by more than order of magnitude between the two models. Consequently, the review panel concludes that it is scientifically unreasonable to expect the two modeling efforts to be in agreement to the extent suggested by LimnoTech.

LimnoTech also ignores the appreciable differences in the history and purposes of the use of two modeling systems in the Chesapeake Bay Watershed. **The review committee finds that LimnoTech ignores the attributes of the CBP model that favor its continued use to inform and guide the TMDL process.** These attributes include the long-term linkages of the CBP watershed model to the estuarine model and their coupled association in developing the Chesapeake Bay TMDL, the long standing peer review and evolution of the CBP watershed model, stakeholder involvement in model reviews and the selection and evaluation of a broad range of pollution management scenarios (i. e., point and nonpoint reductions), and the extensive use of measurements from up to 237 stream and river monitoring sites in the Chesapeake watershed to calibrate and validate the model (Table 1). These attributes of the CBP modeling process stand in stark contrast to those of the relatively new CB-CEAP model, which has a more limited focus, a much shorter history, much less calibration and validation with stream and river measurements, and less independent peer review or stakeholder evaluation of the model results at the Chesapeake Bay watershed level.

Box 2. Modeling BMP effectiveness.

To predict how nutrient and sediment loadings respond to possible watershed management actions, a watershed model must integrate physical, chemical, biological, ecological, economic, and social processes. For many pollution control practices (conservation or best management practices, BMPs), knowledge of the outcomes is always imperfect. Key difficulties in quantifying nutrient or sediment reductions arise from several difficult problems:1) identifying how BMPs perform in "the real world" versus a very carefully controlled research environment, 2) how the BMPs perform over time, 3) how multiple BMPs applied to a given parcel of land interact with each other, 4) how the BMPs influence not only the direct surface delivery of nutrients to streams, but also their delivery over periods of years to decades through the groundwater system (which ultimately may deliver those nutrients to the streams at a substantial distance from the fields where the practice is applied), and 5) how many BMPs are actually implemented in the watershed and whether they are being well maintained over time. Evaluating effectiveness is a daunting challenge that needs the expertise of many disciplines and long-term monitoring of the actual water-quality outcomes of BMPs in the modeled watershed. Enhancing the reliability of any watershed model for use in TMDL analysis requires verifications of actual improvements in water quality due to changes in practices and sources at many scales over many years.

The CBP model deals with these questions through the use of expert panels that incorporate information from the best available research studies and modeling analysis to describe the anticipated outcomes of a wide range of BMPs. The results of many USDA studies are included in CBP model estimates of BMP effectiveness, and the new results from the CB-CEAP analysis can be useful additions to this body of knowledge. But, it must be stressed that estimation of the water-quality benefits of conservation practices is still highly uncertain and needs to be further informed by many sources of information, especially by comparisons between predicted changes in water quality and water quality observations integrated over large areas and long time periods.

The CB-CEAP analysis does not, and was not intended to verify the in-stream effects of conservation practices, because the approach does not include any analysis of observed water quality before and after BMP implementation (USDA-NRCS 2011). Instead, the conservation-related changes in water quality as described in the CB-CEAP model report are simply the results of model simulations that switch conservation practices "on" and "off", based on knowledge of the types and locations of practices from CEAP survey data and model assumptions about the effects of these practices on nutrient and sediment losses from cultivated lands.

Critique of Specific LimnoTech Report Analyses

LimnoTech listed several specific concerns about differences between the two models, related to assumptions about cropland area and the effects of conservation practices, the model frameworks and process representations (hydrology, time step, and simulation time period), and model load predictions. LimnoTech argued that the differences in these attributes of the models are sufficient to warrant a delay in implementing the Chesapeake Bay TMDL requirements until the models can be fully reconciled. The review committee assessed the factual basis for the model statistics as reported by LimnoTech to determine whether the model comparisons were conducted in a fair manner (or were misrepresented) and whether the comparisons used the best available information reported for each of the models. Several of the most significant errors in the LimnoTech report are described below.

Differences in load estimates

The review committee finds that LimnoTech committed notable errors in their comparisons of the loads of both models, such that the load values reported in the LimnoTech report tables and figures are not accurate (Tables 2-4). LimnoTech used CBP model predictions for 2009 land use and land management conditions rather than results that are available for 2005, which are more comparable to the 2003-2006 conditions considered by the CB-CEAP model. In addition, LimnoTech compared controllable nutrient or sediment loads from the CB-CEAP model to total nutrient or sediment loads from the CBP model. The total load from crop fields can be divided into two components, the background load that would be expected if the fields were in a non-agricultural use (like grassland or forest) and the additional load (the controllable load) generated by agricultural activities (tillage, fertilization, manure application, etc.). One could legitimately compare controllable loads from the CBP to controllable loads from CB-CEAP, or CBP model total loads to CB-CEAP total loads. However, the comparison of CB-CEAP controllable load to the CBP model total loads as presented in the LimnoTech report is an "apples to oranges" comparison.

The review committee finds that when errors in LimnoTech's interpretations of the CB-CEAP nutrient and sediment loads are corrected, the simulated nutrient and sediment loads from the two modeling efforts are closer to each other than reported by LimnoTech. For nitrogen and sediment (Table 2), the committee calculates that differences between the total agricultural loads of the two models for nitrogen and sediment are 15% and 29%, respectively. By contrast, the differences in loads as reported by LimnoTech (28% and 67%, respectively) were about twice as large as the corrected estimates. Even without the corrections, the review panel believes that, given the uncertainties associated with the predictions of the two modeling efforts (and watershed models in general), the predictions are within the likely margins of error of the two models and are therefore probably not significantly different. The difference between the corrected load estimates of the two models for phosphorus (28%) is similar to that reported by LimnoTech (26%). Corrected estimates of the differences between the two models in the estimated fractions of the total agricultural load entering the Chesapeake Bay from four major regional basins (Table 3) are within about 6% for nitrogen for all but one basin (Upper Chesapeake) and within 10% for phosphorus for two basins, with differences of about 40% observed for phosphorus in the other two basins (Susquehanna, Lower Chesapeake). For sediment, differences in model predictions range from about 10% to 20% for all but one basin (Upper Chesapeake).

Table 2. LimnoTech (2011) and corrected estimates of total agricultural loads delivered to the Bay.

	Nitrogen (1000 pounds)			Phosphorus (1000 pounds)			Sediment (1000 tons)		
Analysis	CB-CEAP	CBP	Ratio*	CB-CEAP	CBP	Ratio*	CB-CEAP	CBP	Ratio*
LimnoTech	142.1	111.1	1.28	5.4	7.3	0.74	850	2585	0.33
Corrected	148.5	128.7	1.15	5.8	8.1	0.72	2018	2850	0.71

*Ratio of CB-CEAP to CBP predicted load.

Table 3. Corrected fractions of the total agricultural loads delivered to the Bay from major basins.

	Nitrogen (percent of total load)			Phosphorus (percent of total load)			Sediment (percent of total load)		
Basin	CB-CEAP	CBP	Ratio*	CB-CEAP	CBP	Ratio*	CB-CEAP	CBP	Ratio*
Susquehanna	53.1	55.3	0.96	34.8	24.6	1.42	37.8	34.0	1.11
Upper Chesapeake	16.1	12.4	1.30	19.6	18.3	1.07	12.4	7.0	1.77
Potomac	20.6	22.0	0.94	28.6	29.9	0.96	28.4	32.3	0.88
Lower Chesapeake	10.2	10.3	0.98	17.0	27.2	0.62	21.4	26.7	0.80

*Ratio of CB-CEAP to CBP percentage.

Based on the corrected CB-CEAP loads (Table 2), predictions of the percentages of the total loads delivered to the Bay that are attributed to agriculture by the two models (Table 4) show close agreement for nitrogen and phosphorus. For nitrogen, cropland represents 31% and 32% of the total loads from the CB-CEAP and CBP model simulations, respectively, whereas total agricultural loads (from crop, hay, and pasture lands and from animal feeding operations) represent 48% and 47%, respectively. For phosphorus, cropland represents 25% of the total loads in both models, whereas agricultural loads represent 39% and 45%. The agricultural sediment loads show much larger differences—i.e., 15% and 35% reflect cropland contributions to the total loads, whereas 30% and 66% reflect agricultural contributions for the CB-CEAP and CBP models, respectively.

Table 4. Corrected predictions of the percentage of the total load attributed to cropland and total agricultural sources.

	Nitrogen (percent of total load)			Phosphorus (percent of total load)			Sediment (percent of total load)		
Agricultural Source	CB-CEAP	CBP	Ratio*	CB-CEAP	CBP	Ratio*	CB-CEAP	CBP	Ratio*
Cropland	31	32	0.96	25	25	1.01	15	35	0.44
Total agriculture#	48	47	1.02	39	45	0.87	30	66	0.45

*Ratio of CB-CEAP to CBP percentage.
#Loads from crop, hay, and pasture lands and from animal feeding operations.

The review committee finds that the differences in the loads attributed to cropland and total agriculture between the CBP and CB-CEAP models are small, especially in view of the acknowledged differences in the characteristics and purposes of the two modeling efforts. This offers encouragement that, at least over very large spatial scales, the models display many similarities in nutrient and sediment loadings. **More importantly, the results of the two models are similar in their assessment of the need for implementing more management practices on cropland.** The similarities in load estimates are generally consistent with CB-CEAP and CBP modeling reports of model calibration and validation results, which show evidence of approximate agreement between the predictions of both models and monitored loads (monthly and annual) for several of the largest watershed outlets in the Chesapeake Bay region (Kannan et al. 2011, USEPA 2010a, Phase 5.3 Model Calibration). However, the review committee cautions that these comparisons alone provide an insufficient basis for evaluating differences in the performance of the two models. More systematic evaluations (such as those already initiated by the USDA and the CBP) are needed to assess differences in the dynamics of the models and the load response to a range of key processes, including hydrology and agricultural practices. Evaluations are also needed of the performance of the models, particularly CB-CEAP, against available stream monitoring data across a wider range of spatial scales.

LimnoTech also argues that differences exist between the two models in their assumptions about current agricultural practices and the magnitude and location of managed load reductions that are likely to be attainable to satisfy the TMDL requirements. The review committee finds it unremarkable that the models evaluate the outcomes (downstream effects) of different management scenarios differently given that the two modeling efforts clearly have different objectives. These differences in scenario outcomes are not indicative of weaknesses or inconsistencies in the models, but instead reflect the different intended uses and designs of the models. For example, the CB-CEAP management scenarios were designed to illustrate potential environmental benefits based on model assumptions about the controlling processes and the effectiveness of agricultural BMPs. The USDA acknowledges that their scenarios were not designed to represent actual options for the Chesapeake Bay region (USDA-NRCS 2010, 2011). In contrast, the CBP model scenarios are based on stakeholder input and reflect a summary of state and local governmental choices about feasible pollution management actions. The CBP model scenarios are based on the development of watershed implementation plans (WIPs) by state and local stakeholders that describe how each jurisdiction will meet its share of the TMDL-related nutrient and sediment reductions. The review committee's understanding is that these stakeholders (not the CBP) proposed how much of the necessary load reduction will be achieved by the agricultural sector and what type of management practices were included in each state's WIP to meet their target TMDL loads. Therefore, the assumed 20% change in cropland acreage (conversion of cropland into other land uses) that is cited as a concern by LimnoTech actually reflects the integrated outcome of a mix of state and local choices and serves to represent the aggregate effects of this collection of management activities in the model.

Finally, LimnoTech argues that there is an inconsistency in the nutrient and sediment yields between the two models at the field scale that may relate to differences in the scale of the CBP model calibration and the information used to inform the estimates in the CB-CEAP suite of models. LimnoTech suggests that the CBP model yields for cropland are not accurate because there is no calibration at the "edge-of-field", and that the larger scale calibration can lead to field-scale estimates that are too high or low, relative to the approach used in the CB-CEAP model to represent field-scale export. However, the CB-CEAP study did not conduct edge-of-field calibrations and validations either, and CB-CEAP makes no claims of edge-of-field accuracy. Instead, the CB-CEAP report states that the statistical sample used to estimate BMPs for cultivated cropland is too small to allow reliable and defensible reporting of results for areas smaller than a 4-digit hydrologic unit code subregion (USDA-NRCS 2011, page 19). These regions average about 16,000 square miles in area. It is also important to note that the USDA APEX model applications to the Chesapeake Bay regions were not calibrated to field data for the region. Instead, USDA APEX predictions of runoff from cropland are based on field studies that reflect farm runoff under a range of climatic and soil conditions and conservation practices nationwide; these conditions may not be fully representative of those in the Chesapeake Bay region. The lack of formal calibration of the CB-CEAP model (SWAT), except at the 4-digit HUC scale, to monitored load data for Chesapeake Bay streams raises questions about how well the CB-CEAP predictions of nutrient and sediment runoff from croplands reflect actual conditions. It is the opinion of the review committee, that despite the recognized shortcomings of the CBP and CB-CEAP models, the extensive use of stream monitoring data to calibrate the CBP model is an informative modeling practice that helps provide equitable and balanced local and regional predictions of nutrient and sediment export from cropland and other land uses and delivery to downstream waters. Evaluations of the performance of both models against commensurate measurements of water quality should be conducted across a wide range of locations and conditions in the watershed to provide a more informed understanding of model differences. The Committee is concerned that LimnoTech failed to consider or discuss this more appropriate method for evaluating model performance.

Differences in drainage areas

LimnoTech noted a 2.1% difference between the CBP and CB-CEAP models in the estimated total area of the CB watershed (LimnoTech 2011). Such a difference could arise from differences in the topographic data, stream maps, or analysis procedures used to map watershed outlines. The review committee did not pursue the difference in watershed areas, but believes it is an appropriate topic to consider in the follow-up efforts of USDA and EPA model comparisons (see the section on Recommendations for Integrating Models).

Differences in agricultural land area

LimnoTech also notes that the CBP and CB-CEAP models differ in the amounts of agricultural land, including USDA's reporting of additional acreage in conservation tillage. The acres of conventional-tilled acres versus conservation tilled acres vary considerably between the two reports and this concern is legitimate. The Chesapeake Bay Program (CBP) estimates of the two types of cropland were derived from state inventories of cost-shared BMPs and the latest distributions between the two types by county from the Conservation Tillage Information Center (CTIC, Gary Shenk, USEPA-CBP, personal communication). Unfortunately the latest data from CTIC was in 2002, so these data are not reflective of recent shifts between the two. While the percentage of conservation tillage varies from county to county, the cited overall average of 50% gives the impression that this was some arbitrary value. The CBP also acknowledges that these values are low and do not include acreages of conservation tillage implemented on a voluntary basis, which could be substantial. The NRC Review Committee concluded that "a consolidated regional BMP program to account for voluntary practices and increase geo-referencing of BMPs presents opportunities to improve the tracking and account process (NRC 2011). CBP is currently working with the states to incorporate verified voluntary conservation tillage acreages in their annual inventories. The review committee finds that agricultural areas are closer in size when Conservation Reserve Program areas (CRP) and hay/pasture rotations are treated equivalently. Currently the CB-CEAP model counts CRP land as agricultural land, whereas the CBP model does not. Therefore, the inclusion of CRP and hay areas may explain the higher agricultural land area in the CB-CEAP model (Lee Norfleet, USDA-NRCS, personal communication).

Differences in BMP acreage

The CB-CEAP report states that producers use some kind of residue, tillage, or structural management practices on 94% of cropped acres. The LimnoTech report quotes CB-CEAP as saying that producers use residue, tillage, structural practices on 96% of cropped acres. In the CBP model, about 90% of cropped acres have at least one conservation practice applied to them.

The CBP model scenario builder

LimnoTech acknowledges that the CBP model has been tested and reviewed, but expresses concerns that the "scenario builder" component has not been reviewed and its accuracy is unknown. LimnoTech states that "Scenario Builder is not a complete agricultural model and it has significant limitation. It was not designed to be full crop growth model ... [and] is used to represent farm scale operations." The review committee agrees that the scenario builder is a key component of the CBP modeling framework and is important in representing the level of implementation and effectiveness of BMPs in the CBP model. However, scenario builder is not a simulation, but a tool for assembling the inputs needed to represent particular scenarios (USEPA 2010a, Scenario Builder Documentation). Those inputs are in turn supplied to the CBP watershed simulation model, which handles the crop simulation. It is the opinion of the review committee that the scenario builder and its role in the CBP model have been extensively reviewed by stakeholders in several workgroups within the Bay program, and it has been judged adequate for its intended purpose at the current time. The underlying BMP efficiency data have been examined by external peer review committees (Pease et al. 2007, 2008). We agree that the scenario builder should evolve over time to better represent BMPs in the CBP model system, and we believe that the CB-CEAP modeling approach may provide useful insights for achieving those improvements.

Modeling agricultural practices

The committee is concerned that LimnoTech is misinformed about how the CB-CEAP and CBP models characterize agricultural practices. First, LimnoTech asserted that the CBP model lacks temporal variability in agricultural practices. This is not the case as both the CB-CEAP and CBP models account for temporal variations in a variety of practices, including crop rotations and management practices. Second, LimnoTech cites differences in how animal manure sources are simulated in the two models. These differences are explained by fundamental differences in the structure of the two models and the importance assigned to these sources by the model developers. The CBP model includes estimates of manure nutrient runoff from animal feeding operations, which are considered to be an important agricultural source of nutrients that must be evaluated as part of the TMDL process. In contrast, the CB-CEAP model divides all manure into a recoverable fraction (which is applied to cropland, hayland, and pasture) and a non-recoverable fraction, which is assumed to be dispersed onto pasture land (Lee Norfleet, USDA-NRCS, personal communication). CB-CEAP's simulation of nutrient runoff from animal feeding operations is less explicit than the treatment in the CBP model because the primary purpose of the CB-CEAP model is to evaluate the effectiveness of farm conservation practices on cultivated cropland. The review committee agrees with LimnoTech that the CB-CEAP model includes many realistic details about agricultural operations and management (e. g., crop rotations, more levels of tillage [no-till, mulch till, conventional till], actual nutrient management practices, etc.) that are not considered in the CBP model. However, comparisons to observed nutrient and sediment loads must still be done to determine if the additional model detail actually yields better predictions of nutrient and sediment loads.

Recommendations for Integrating Models

The existence of multiple models for the Chesapeake Bay watershed can help to inform science and management efforts to reduce nutrient and sediment pollution. Although the new CB-CEAP analysis does not provide information to delay TMDL implementation, the CB-CEAP model framework does provide valuable information that can inform and improve the CBP model and its future application to the TMDL. CBP and USDA modelers have already begun integrating their two approaches. The modelers began talking informally in the summer of 2010 (before the publication of both the CB-CEAP and LimnoTech reports to compare results and consider possible collaborations. Those efforts have matured into a formal agreement to undertake a range of cooperative activities to identify where information from the two activities can be effectively harmonized and where NRI and CEAP results can inform TMDL modeling with the CBP model (see Appendix). The review committee commends the two agencies for undertaking these collaborative activities, and offers suggestions for additional integrative and collaborative activities below.

The CBP to CB-CEAP comparison does not support delaying TMDL implementation

The review committee finds no reasonable scientific basis to support LimnoTech's admonition to delay the implementation of the Chesapeake Bay TMDL. The existence of differences between the CBP and CB-CEAP models does not support a delay. Differences are expected because the two models were developed for different purposes and exploited different approaches and data sources that were appropriate for their individual objectives. Delaying the TMDL to resolve all the differences and build a so-called "correct" model will only delay Chesapeake Bay restoration. The CBP and CB-CEAP models both indicate that additional agricultural conservation practices for cropland are needed, and there is little risk that initial management actions will go farther than is needed.

Implement TMDL requirements in an adaptive management framework

Adaptive management (not delay or inaction) is the proper response to uncertainty in knowledge, including differences between models. Adaptive management (Box 3) arose from the recognition that uncertainty is inherent in natural systems, yet management actions cannot be indefinitely delayed until knowledge is complete and uncertainties are resolved (NRC 2011). TMDL plans should use adaptive management methods (e. g., NRC 2011) to ensure that programs are not halted for lack of information, but rather progress while better information is collected (NRC 2001). That new information will reflect changes in the watershed and new understanding gained from ongoing water quality monitoring and modeling and from new research on water quality responses to management actions. With adaptive management, knowledge of the effects of BMPs on water quality and the modeling of those effects will evolve in parallel with regulations and management actions.

The Chesapeake Bay TMDL offers some adaptive management flexibility through its two year milestones and its planned recalibration of the model and reevaluation of progress and goals in 2017. To fully implement adaptive management, the NRC (2011) recommended that the CBP refine its understanding of adaptive management, better analyze the uncertainties relevant to nutrient and sediment reduction efforts and water quality outcomes, implement targeted monitoring programs, and ensure sufficient flexibility in accountability and regulatory and organizational structures.

Box 3. Adaptive management.

Adaptive management arose from the recognition that uncertainty is inherent in natural systems, yet management actions cannot be indefinitely delayed until knowledge is complete and uncertainties are resolved (NRC 2011). USDA scientists have reviewed the adaptive management literature (Stankey et al. 2005), and concluded that effective approaches to adaptive resource management involve a structured, iterative process of decision making that attempts to reduce uncertainty through the use of continuous feedback from new knowledge and understanding. The Chesapeake Bay TMDL's pollutant load allocations and required reductions represent the CBP's current best professional judgment of reductions that will meet the Clean Water Act's requirements. With adaptive management, the goal is the attainment of water quality standards and not the attainment of specified waste load reductions. As the Bay TMDL is implemented, the effects of implementation efforts will be continuously assessed for their impacts on water quality, and the TMDL requirements should be adjusted as more knowledge is gained about the effectiveness and social/economic feasibility of alternative implementation approaches. For example, over time and in response to implementation of BMPs and to improved data and models, water quality monitoring results may indicate that one sector has more or less responsibility for pollutant loadings in a particular watershed than was originally thought. If so, the TMDL load allocations would be refined to reflect this new information and reallocation would follow to meet water quality goals.

The concept of adaptive management involves systematically testing assumptions, not a trial and error process. It involves adaptation as new information challenges current assumptions and suggests improved interventions. It involves learning as a fundamental process that reduces uncertainty. The committee views the introduction of new modeling perspectives as part of the process of adaptive resource management, and we commend the EPA and USDA for implementing a constructive dialog to arrive at the best way forward to meet the Clean Water Act's requirements. The applicability of adaptive management to Chesapeake Bay restoration was explicitly considered in a full chapter in the recent report of the National Research Council's Committee on the Evaluation of Chesapeake Bay Program Implementation for Nutrient Reduction to Improve Water Quality (NRC 2011). The review committee agrees with the NRC findings, which are summarized in the following quote from their report summary (NRC 2011, page 6): "Effective adaptive management involves deliberate management experiments, a carefully planned monitoring program, assessment of the results, and a process by which management decisions are modified based on new knowledge. Learning is an explicit benefit of adaptive management that is used to improve future decision making."

Apply a multiple modeling strategy

The review committee believes that having a suite of models built on different representations of processes, different spatial and temporal resolutions, and different approaches to calibration and validation with observational data is useful and yields better predictive capability in the long run than relying on a single model. For nearly two decades, the CBP model was the only modeling effort that attempted to comprehensively model the entire Chesapeake Bay watershed. SPARROW (Preston and Brakebill 1999) was built in 1997 using a very different spatial, temporal, and process construct; and it has added new insights that have led to improvements in the CBP model. In the last year, the CB-CEAP model has emerged as a third model of the Chesapeake watershed, and it brings new approaches to modeling land use and agricultural practices. This third model can continue the pattern of improving predictive modeling of the Chesapeake Bay Watershed through model comparison and integration. The review committee commends EPA and USDA for already undertaking model inter-comparison, and we recommend that those efforts be enhanced as described below. The review committee emphasizes that recommending analyses of multiple models does not undermine the use of the existing CBP model or provide a rationale for halting TMDL implementation.

Integrate knowledge from the CB-CEAP project into the CBP model

The CB-CEAP effort provides new knowledge about the way that BMP implementation can be expected to reduce nutrient and sediment loads from cultivated cropland. That knowledge can enhance the CBP model and its application to the TMDL. CB-CEAP's use of site-specific data from the NRI and from additional farmer surveys to characterize cropland management is an important development. For example, CEAP's farmer surveys suggested that voluntary conservation practices are implemented at much higher levels than previously accounted for (USDA-NRCS 2010, 2011). CEAP also provides new data and statistical summaries of the amounts of cropland with conventional tillage or conservation tillage. This approach should also be considered for non-cultivated cropland land uses. These results would be very helpful in identifying other spatial and temporal factors that cause variation in practice effectiveness. The review committee recommends that the CBP, USDA, and state and local partners continue their ongoing collaborative efforts to assemble better data on verified voluntary BMPs and other BMPs on agricultural lands (Chesapeake Bay Executive Order Strategy http://executiveorder.chesapeakebay.net/ and Joint CBP-USDA agreement, Appendix) and to incorporating the new information into the CBP model. Those efforts will implement and exploit the consolidated program for tracking and geo-referencing BMPs recommended by the NRC (2011).

Enhance comparability and improve all Chesapeake Bay watershed management models

Standardization of data where appropriate. As noted above, models created for different purposes must often use different, conceptualizations, algorithms, or data sources. Despite those necessary differences, there are opportunities for greater standardization among models. For example, CBP and USDA could adopt the same Chesapeake watershed boundary data set for their two modeling efforts. The review committee recommends that the CBP and USDA work together with other organizations interested in the Chesapeake to identify and implement such opportunities for standardization.

Estimation of prediction uncertainties. The review committee recommends that both models attempt to estimate uncertainties in key predictions (NRC 2001, Band et al. 2005, 2008) in order to help decision makers understand the variability of natural systems and to provide them with additional information for their analyses. Model uncertainty estimates will facilitate objective assessment of the significance of differences between models.

Improved access to critical data. The review committee notes that the CB-CEAP model relies on confidential USDA data from the NRI (National Resources Inventory) and from confidential farmer surveys. Such information has not been available for use by the CBP because of restrictions established by the US Congress on the use of site specific agricultural data. Restricted access to USDA data has limited their past use in developing the CBP model and continues to limit independent analysis and critical review by academic and other non-USDA scientists. The review committee recommends that USDA and the CBP work together to relax restrictions on the use of site-specific farm data by the CBP and for other water quality management planning purposes, while maintaining protection of individual farmer confidentiality. The committee also recommends that USDA report data at the highest spatial resolution that will not violate mandated confidentiality restrictions. We understand USDA's desire to only publish statistically significant cropland characteristics at the resolution of 4-digit

HUCS (USDA-NRCS 2010, 2011), but the ranges and spatial distributions of the cropland characteristics at higher resolution could inform many other analyses and management efforts.

Improved model accounting for lag times associated with BMPs. Both models assume actions have immediate impact, but there are groundwater, soil response, and instream lag times associated with BMP implementation and hydrologic transport that neither model represents as well as is it could. Both models overestimate the immediate impact of BMPs. The review committee recommends development of modeling approaches that can account for groundwater lag-time, sediment deposition and remobilization, and nutrient cycling in soils and aquatic environments in future revisions of each modeling framework.

More extensive calibration, validation, and discretization of CB-CEAP. If the CB-CEAP model is to become a more useful component of the suite of Chesapeake Bay management models, it should be recalibrated and revalidated with a larger subset of the water quality monitoring stations at which the CBP model has been calibrated and validated (Table 1). CB-CEAP could also provide output at the level of spatial resolution as the CBP model for all land uses. This would allow a more direct comparison of the results of the two models and help better define uncertainties in the models' predictions and in the Chesapeake Bay TMDL.

Utilization of CB-CEAP submodels to estimate field/watershed specific BMP effectiveness. The CB-CEAP model could be analyzed to yield effectiveness estimates for different BMPs or systems of BMPs. These CB-CEAP efficiency estimates could be compared to the scientific literature and to the estimates used in the CBP model. These CB-CEAP simulations could help identify the spatial and temporal factors that cause variation in practice effectiveness, which could inform future refinements of the CBP model.

Continued model development. Models used in the Chesapeake Bay restoration efforts/TMDL should not be static. They should evolve as our knowledge of the Chesapeake Bay watershed increases and there are roles for use of additional models such as CB-CEAP.

Subject Chesapeake Bay Watershed management models to regular peer review

The review panel recommends that all models used in making Chesapeake Bay management decisions should be periodically independently reviewed to identify model shortcomings and to improve the predictive abilities of the models. Peer review is an important tool for improving the quality of scientific products and is basic to all stages of model evaluation. The CBP and CB-CEAP models both contain components (such as the HSPF, APEX, or SWAT models) that have been extensively peer-reviewed in the scientific literature. The CBP model (Band et al 2005, 2008) and some of its components (Pyke et al. 2008, Pease et al. 2007, 2008; Pyke 2010) have had several independent peer reviews and those reviews should continue at regular intervals. The CB-CEAP implementation is new and could benefit from similar regular, independent, external reviews of the complete modeling system and its application to the Chesapeake watershed.

Compare models to observed data as well as to other models

Comparing the predictions of models (e. g., LimnoTech 2010, 2011) is useful to help understand modeling uncertainty, but real assessment of model performance requires comparing model predictions to observed data. Comparing how well the CBP and CB-CEAP models simulate the observed status and trends in water quality across the watershed as influenced by cultivated cropland could help guide future enhancements of the both models and help characterize uncertainties associated with model outputs.

Promote a realistic understanding of the uncertainties associated with watershed models

Use of multiple models and model comparisons. The CBP partnership could host workshops and subsequent activities to better define how multiple models and model comparison can be more effectively used in managing the Chesapeake Bay.

Improved public understanding of models and their uncertainties. The CBP could sponsor a social science workshop on how models, differences in models, and model uncertainty are perceived by non-scientists, and on how these issues can be better communicated to decision makers and to the public.

References

Band, L., K. Campbell, R. Kinerson, K. Reckhow, and C. Welty. 2005. Review of the Chesapeake Bay watershed modeling effort. STAC Publication 05-004, Chesapeake Research Consortium, Inc., Edgewater, MD.

Band, L., T. Dillaha, C. Duffy, K. Reckhow, and C. Welty. 2008. Chesapeake Bay watershed model phase five review. STAC Publication 08-003, Chesapeake Research Consortium, Inc., Edgewater, MD.

Kannan, N., S. Chinnasamy, M. White, J. Arnold, M. Di Luzio, and X. Wang. 2011. Documentation on calibration and validation of CEAP-HUMUS for various river basins in the United States. USDA-Agricultural Research Service, Temple, TX. Available at: http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1044544.pdf

LimnoTech. 2010. Comparison of draft load estimates for cultivated cropland in the Chesapeake Bay watershed. LimnoTech, Ann Arbor, MI.

LimnoTech. 2011. An updated Comparison of load estimates for cultivated cropland in the Chesapeake Bay watershed. LimnoTech, Ann Arbor, MI.

NRC. 2001. Assessing the TMDL approach to water quality management. Committee to Assess the Scientific Basis of the Total Maximum Daily Load Approach to Water Pollution Reduction, Water Science and Technology Board, National Research Council. The National Academies Press, Washington, DC.

NRC. 2007. Models in environmental regulatory decision making. Committee on Models in the Regulatory Decision Process, Board on Environmental Studies and Toxicology, National Research Council. The National Academies Press, Washington, DC.

NRC. 2011. Achieving nutrient and sediment reduction goals in the Chesapeake Bay: An evaluation of program strategies and implementation. Committee on the Evaluation of Chesapeake Bay Program Implementation for Nutrient Reduction to Improve Water Quality, Water Science and Technology Board, National Research Council. The National Academies Press, Washington, DC. (Prepublication copy).

Pease, J., M. B. A., S. Mostaghimi, M. Walbridge, D. Hansen. 2007. Review of procedures for the MAWQ/UMD best management practice project, Year 1. STAC Publication, Chesapeake Research Consortium, Inc., Edgewater, MD.

Pease, J., S. M., D. Hansen, D. Sample, D. Beegle, S. Hodges. 2008. Review of procedures of the UMD/MAWP best management practice project, Year 2. STAC Publication 08-005, Chesapeake Research Consortium, Inc., Edgewater, MD.

Preston, S. D. and J. W. Brakebill, 1999. Application of Spatially Referenced Regression Modeling for the Evaluation of Total Nitrogen Loading in the Chesapeake Bay Watershed. In: US Geological Survey Report WRIR-99-4054, pp. 1-16.

Pyke, C., G. P., D. Parker, J. Kittle, B. 2008. Chesapeake Bay land change modeling technical review. STAC Publication, Chesapeake Research Consortium, Inc., Edgewater, MD.

Pyke, C. 2010. Review of land-use and land cover dataset and methodology. STAC Publication, Chesapeake Research Consortium, Inc., Edgewater, MD.

Stankey, George H.; Clark, Roger N.; Bormann, Bernard T. 2005. Adaptive management of natural resources: theory, concepts, and management institutions. Gen. Tech. Rep. PNW-GTR-654. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 73 p.

USDA-NRCS. 2010. Review draft October 2010--Assessment of the effects of conservation practices on the cultivated cropland in the Chesapeake Bay region. U. S. Dept. of Agriculture, Natural Resources Conservation Service, Washington, DC
USDA-NRCS. 2011. Assessment of the effects of conservation practices on the cultivated cropland in the Chesapeake Bay region. U. S. Dept. of Agriculture, Natural Resources Conservation Service, Washington, D.C.
USEPA. 2010a. Chesapeake Bay Phase 5 Community Watershed Model In preparation EPA XXX-X-XX-010 Chesapeake Bay Program Office, Annapolis, Maryland. December 2010. Available at http://www.chesapeakebay.net/model_phase5.aspx?menuitem=26169.
USEPA. 2010b. Chesapeake Bay Total Maximum Daily Load for Nitrogen, Phosphorus and Sediment. U. S. Environmental Protection Agency, Washington, DC. Available at: http://www.epa.gov/reg3wapd/tmdl/ChesapeakeBay/tmdlexec.html.

List of Acronyms

ANPC	Agricultural Nutrient Policy Council
ARS	Agricultural Research Service
BMP	Best Management Practice
CBP	Chesapeake Bay Program
CEAP	Conservation Effects Assessment Project
CRP	Conservation Reserve Program
CTIC	Conservation Tillage Information Center
EPA	United States Environmental Protection Agency
HRU	Hydrologic Response Unit
HUC	Hydrologic Unit Code
NRC	National Research Council
NRCS	Natural Resources Conservation Service
NRI	National Resources Inventory
STAC	Scientific and Technical Advisory Committee
TMDL	Total Maximum Daily Load
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WIP	Watershed Implementation Plan

List of Model Names

APEX	Agricultural Policy Environmental EXtender
CB-CEAP	model of the effects cropland conservation practices in the Chesapeake watershed
CBP model	Chesapeake Bay Program watershed model
HUMUS	Hydrologic Unit Model for the United States
SPARROW	Spatially Referenced Regressions on Watershed Attributes
SWAT	Soil and Water Assessment Tool

Appendix: EPA-USDA Collaborative Agreement

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

JUN 28 2011

OFFICE OF CONGRESSIONAL AND INTERGOVERNMENTAL RELATIONS

The Honorable Glenn Thompson
Chairman
Subcommittee on Conservation, Energy, and Forestry
Committee on Agriculture
U.S. House of Representatives
Washington, D.C. 20515

Dear Chairman Thompson:

At the Subcommittee on Conservation, Energy and Forestry hearing about the Chesapeake Bay in March, the USDA and the EPA stated their intention to continue efforts to refine and increase the level of data available for understanding the implementation of conservation practices by farmers in the Chesapeake Bay Region. To ensure that the work continues to progress, the EPA and the USDA scientists have developed a plan of work for the key activities that are expected to be accomplished. A copy of the plan of work for that effort is enclosed.

The additional data and refinements will serve a set of key purposes that will:

- Account for agricultural conservation practices implemented throughout the Chesapeake Bay watershed, including those practices funded solely by the farmer (not funded by federal or state cost share funding).
- Develop, as appropriate and feasible, a consistent estimate of pasture and hay land acres for use by the EPA and the USDA.
- Develop, as appropriate and feasible, a consistent approach for estimating fertilizer and manure applications for use by the EPA and the USDA.

In addition, there is ongoing work to 1) update and refine current conservation practice effectiveness estimates; and 2) credit new conservation practices as they are applied in the field. These efforts are intended to reflect our long term commitment to ensuring the best possible data is available. As a result of this work, we hope to increase our understanding of the impact of conservation practices and of the contribution farmers are making to restoration of the Bay.

We appreciate your interest in this important issue and will be glad to provide additional information that you may request.

Sincerely,

Arvin R. Ganesan
Associate Administrator

Enclosure

U.S. Department of Agriculture (USDA) and U.S. Environmental Protection Agency (EPA) Chesapeake Bay Conservation Data Collaboration

In December 2010, the EPA released the final Total Maximum Daily Load (TMDL) for the Chesapeake Bay. TMDL nutrient and sediment load allocations for the Bay Watershed States were developed using water quality monitoring data and a suite of models, including the Chesapeake Bay Program Watershed Model.

In March 2011, the USDA released its Assessment of the Effects of Conservation Practices on Cultivated Cropland in the Chesapeake Bay Region, a document known familiarly as the Chesapeake Bay Conservation Effects Assessment Project, or CEAP report. The USDA's CEAP effort is based on a combination of farmer surveys and modeling used to estimate the impact of conservation practices on the landscape.

There is a lot of interest from Chesapeake Bay stakeholders and within the USDA and the EPA to ensure consistency between the two modeling efforts and that they are informed by the best data available describing implementation of conservation by farmers in the Chesapeake Bay region. Below are commitments by the two agencies to that end.

Improve tracking and reporting of conservation practices in the Chesapeake Bay Program (CBP) Watershed Model

As called for in the May 12, 2009 Executive Order 13508 - *Strategy for Protecting and Restoring the Chesapeake Bay Watershed,* The USDA and the EPA are working with state agricultural agencies, conservation districts, and other key agricultural groups to ensure that non-cost shared practices are tracked, verified, and reported for credit in the CBP Watershed Model.

Additionally, the USDA is surveying approximately 1,400 producers through the National Resources Inventory (NRI) in 2011 to estimate the level of conservation practice implementation and to refine the spatial scale of available data. Combined with the similar work conducted from 2003-2006 (presented in the 2011 CEAP report), the results of this survey will provide an estimate of additional on-the-ground implementation of conservation practices between the two survey time periods.

Commitments:

The USDA and the EPA will work with state agricultural agencies, conservation districts, and other key agricultural groups to develop a mechanism for tracking, verifying and reporting non-cost shared conservation practices on agricultural lands for use in the CBP Watershed Model.
Timeframe: Complete by July 2012.

Using CEAP results from 2003-2006 and the pending 2011-12 analysis, the USDA and the CBP Partnership will explore inclusion of the additional practices identified in these surveys into the CBP Watershed Model.
Timeframe: Begin in 2012.

Develop consistent estimates of pasture and hay land use in both models

The CBP Watershed Model and CEAP Model use different approaches for estimating pasture and hay land in the Chesapeake Bay watershed. The U.S. Geological Survey developed a methodology for estimating land use for the CBP modeling effort in which the pasture and hay land use is based on the USDA census of agriculture data rather than satellite imagery.

Commitment:
The Natural Resources Conservation Service (NRCS) and the CBP will work together to investigate the appropriateness of using a common approach for estimating pasture and hay land in both models.
Timeframe: Begin in 2011.

Coordinate fertilizer and manure nutrient input assumptions in both models
The NRCS and the CBP independently developed databases to estimate nutrient applications to cropland and arrived at similar figures for total application. However, differences likely exist in application timing and amounts applied by region, crop, and management system. A consistent approach for fertilizer and manure nutrient inputs that is informed by the significant work by the USDA and the CBP partnership would likely improve both models.

Commitment:
The NRCS and the CBP will work together to investigate the development of a single database to estimate nutrient applications to cropland that would drive both modeling efforts, building on the experiences of both. Alternatively, given the different temporal and spatial scales of the modeling, the NRCS and the CBP can work together to standardize assumptions across databases.
Timeframe: Begin 2012 and continue thereafter. Results may be used in CEAP on an ongoing basis and may be used for the CBP management decisions in 2017.

Develop comparable scales for reporting nutrient/sediment loads in CEAP & CBP Models
Commitment:
Currently the two models track and report loads on different geographic scales. Development of common reporting scales will allow a more effective comparison of model findings and increase watershed model data and technique sharing capabilities. As the technologies of the two models advance, opportunities to collaborate should be explored.
Timeframe: Begin 2012 and continue thereafter.

There are two further tasks that are already in progress to ensure that the CBP Watershed Model is informed by the latest scientific data:

Updating current conservation practice effectiveness estimates based on the latest science. The NRCS and the CBP will work with the Agriculture Workgroup to determine the most appropriate way to inform updates to conservation practice effectiveness estimates in the CBP Watershed Model, with a particular focus on characterizing spatial variability in practice effectiveness.
Timeframe: Ongoing

Crediting new conservation practices. The EPA will provide resources to help coordinate the effort to credit new conservation practices in the CBP Watershed Model, in accordance with the established protocols. The USDA will provide relevant data on effectiveness estimates of the new conservation practices to inform assessment by expert panels that evaluate practice effectiveness.
Timeframe: Ongoing

MISSISSIPPI RIVER COLLABORATIVE

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June 23, 2011

The Hon. Bob Gibbs
Chairman
Committee on Transportation
and Infrastructure
Subcommittee on Water
Resources and Environment
U.S. House of Representatives
Washington, DC 20515

The Hon. Timothy H. Bishop
Ranking Member
Committee on Transportation
and Infrastructure
Subcommittee on Water
Resources and Environment
U.S. House of Representatives
Washington, DC 20515

Re: Nitrogen and Phosphorus Pollution

Dear Representatives Gibbs and Bishop:

Thank you for allowing our organizations - members of the Mississippi River Collaborative (MRC) - to provide our perspective on the urgent issue of controlling nitrogen and phosphorus pollution.

For reasons well documented in reports by the National Research Council, including the landmark review titled, "Mississippi River Water Quality and the Clean Water Act: Progress, Challenges and Opportunities," as well as the June 30, 2008 Petition for Rulemaking of our groups to the United States Environmental Protection Agency (USEPA), and other attached documents, it is vital to protect drinking water, the economy and the aquatic environment through the prompt establishment of numeric nutrient criteria for all of the waters of the United States. As part of a broader effort to control nitrogen and phosphorus pollution that uses many legal and technological tools, USEPA must continue to urge states to develop numeric criteria and, where necessary, must step in to do so itself.

The effects of nitrogen and phosphorus pollution are dire and well-known. Nitrogen and phosphorus pollution has:

- Fueled algae blooms that filled water supplies with toxic cyano-bacteria and total organic carbon which requires costly treatment that itself can create carcinogenic by-products;
- Created serious health hazards to swimmers and illness and death of house pets that come into contact with harmful algal blooms in water polluted by nitrogen or phosphorus;
- Ruined recreational opportunities and tourist experiences in many areas of the country, undercutting important sources of jobs;
- Contributed to the formation of a huge summer "dead zone" in the Gulf of Mexico and other waters, killing aquatic life and endangering the livelihoods of fishermen and others who depend on healthy coastal waters; and
- Exacerbated conditions that harm fish and wildlife in numerous rivers, lakes and streams throughout the Mississippi Basin and across the country.

It is clear that the efforts of the states and federal agencies have not been adequate to date. Indeed, as summarized by the State-EPA Nutrient Innovations Task Group:

> [T]he spreading environmental and drinking water supply degradation associated with excess levels of nitrogen and phosphorus in our nation's waters has been studied and documented extensively. Current efforts to control nutrients have been hard-fought but collectively inadequate at both a statewide and national scale. Concern with the limitations of current nutrient control efforts is compounded by the certain knowledge that as the U.S. population increases by more than 135 million over the next 40 years, the rate and impact of nitrogen and phosphorus pollution will accelerate - potentially diminishing even further our progress to date.

State-EPA Nutrient Innovations Task Group, An Urgent Call to Action (Aug. 2009).

Despite repeated urgings by EPA under both Republican and Democratic administrations, states have failed to develop standards and criteria sufficient to protect the Mississippi River, the northern Gulf of Mexico and other valuable waters from worsening nutrient impairments. For example, in 2007, the EPA Assistant Administrator for Water under President Bush wrote:

> Today, EPA is encouraging all States, Territories and authorized Tribes to accelerate their efforts and give priority to adopting numeric nutrient standards or numeric translators for narrative standards for all waters in States and Territories that contribute nutrient loadings to our waterways.

Memorandum of Benjamin H. Grumbles, Nutrient Pollution and Numeric Water Quality Standards, (May 25, 2007).

EPA found in 1998 that numeric nutrient standards are needed for the states. Specifically, the agency stated that "States should have adopted nutrient criteria that support State designated uses by the end of 2003." For those states that failed to adopt needed numeric criteria, the agency warned: "EPA will initiate rulemaking to promulgate nutrient criteria values that will support the designated use of the waterbody and are appropriate to the region and waterbody types." (USEPA, National Strategy for the Development of Regional Nutrient Criteria June 1998.)

The decade following 1998 proved beyond a doubt that EPA must play a lead role in addressing the problem. EPA's Scientific Advisory Board called for direct action "as soon as possible" to reduce both nitrogen and phosphorus loadings "before the system reaches a point where even larger reductions are required to reduce the area of hypoxia." USEPA, Science Advisory Board, Hypoxia in the Northern Gulf of Mexico (2008). Likewise, the National Research Council has pressed EPA to take a more proactive role, recommending that the agency:

- "develop water quality criteria for nutrients in the Mississippi River and the Northern Gulf of Mexico";
- "ensure that states develop water quality standards (designated uses and water quality criteria) and TMDLs such that they protect water quality in the Mississippi River and northern Gulf of Mexico from excessive nutrient pollution"; and
- "develop a federal TMDL..."

National Research Council, Mississippi River Water Quality and the Clean Water Act: Progress, Challenges and Opportunities (2008).

In short, EPA's actions to date have hardly amounted to "riding roughshod" over states, as the title of the subcommittee's hearing suggests. To the contrary, despite years of study, conferences and action plans, the states and EPA have, to date, failed to effectively address nitrogen and phosphorus pollution. The latest example of this pattern is a March 16, 2011 Memorandum from EPA's Acting Assistant Administrator for Water Nancy Stoner to Regional Administrators; this document acknowledges the costly consequences of nutrient pollution and the urgent need to reduce nitrogen and phosphorus loading. Yet, like previous such memos, it fails to establish concrete and enforceable requirements for developing numeric criteria and TMDLs that will maintain and restore water quality. Instead, the Memorandum offers EPA's encouragement and assistance "where states are willing to step forward." We suggest that EPA's faith in state action is misplaced. The Stoner Memorandum itself, for example, cites 1998, 2001, and 2007 studies and memos in which EPA concluded that numeric water quality criteria are necessary to ensure water quality in the Mississippi and northern Gulf waters. Yet, in 2011 not a single state bordering the Mississippi River is calculating permit limits for nutrients based on numeric criteria designed to protect against downstream impacts in the Mississippi River and the Gulf. Few of the states are even calculating nitrogen or phosphorus limits needed to protect the immediate receiving water body of the discharge.

Development of numeric criteria is essential. Total maximum daily load calculations (TMDLs), when fully implemented, can be very useful but TMDLs require a target which will almost always be a numeric water quality standard. NPDES permits must control all pollutants that regulated sources discharge, but writing NPDES permits can be difficult without some sort of numeric target. As history has abundantly shown, this simply cannot effectively be done on case-by-case basis in many cases.

Even control of nitrogen and phosphorus pollution from agriculture is greatly advanced through establishment of numeric nitrogen and phosphorus standards. While pollution from agriculture is largely outside of federal regulatory control (33 USC 1362(14)), state and voluntary programs to control nitrogen and phosphorus pollution from agriculture would greatly benefit from having a numeric target.

Finally, nitrogen and phosphorus control can be accomplished at reasonable cost, despite some estimates. The idea that reverse osmosis or other costly processes will be required of municipalities is absurd – for instance, EPA concluded that it "does not believe that this type of treatment technology for [wastewater treatment plants] in Florida has been demonstrated as practical or necessary." 75 Fed. Reg. 75,762 75,795 (Dec. 6, 2010). Moreover, the law is clear that criteria may be changed for water bodies where it can be shown that applying existing requirements would result in substantial and widespread economic impact. 40 CFR § 131.10(g). Moreover, there are numerous other vehicles under the existing regulations to avoid imposing unreasonable costs. Beyond the inherent flexibility in the law, we urge you to bear in mind the huge cost imposed on the nations' waters and economy by nitrogen and phosphorus pollution.

Last month, the following story appeared regarding what has been a treasured recreational lake in Ohio near which many people live:

> Last updated: May 19, 2011 4:49 p.m.
>
> ## Grand Lake St. Marys warning: Don't swim, wade or touch algae
>
> Associated Press
> ST. MARYS, Ohio – Water warnings are going up again at Ohio's largest inland lake after another algae outbreak.
>
> The state is telling visitors at Grand Lake St. Marys not to swim or wade in the lake because of the algae. It's the same kind that can produce toxins that shut down the lake last summer.
>
> They're also warning against touching any of the algae on the water.
>
> Officials say the algae bloom is visible across the western Ohio lake.
>
> The state is planning to treat the water this summer in hopes of improving quality.
>
> Marinas, campgrounds and other places that count on tourists lost much of their business last year after the state warned against swimming, boating and fishing.

Finally, just last week scientists released a prediction of the size of this year's Gulf of Mexico Dead Zone, stating that it may be 9,421 square miles, or "about the size of the combined land area of New Jersey and Delaware, or the size of Lake Erie...if the [Dead Zone] becomes this large, then it will be the largest since systematic mapping of the [Dead Zone] began in 1985." Also according to the forecast, the Dead Zone "continues to threaten living resources including humans that depend on fish, shrimp and crabs. Excess nutrients, particularly nitrogen and phosphorus, cause huge algae blooms whose decomposition leads to oxygen distress and even organism death in the Gulf's richest waters."

We pray that Congress not take any action that will make such reports still more prevalent. Instead, the Committee should urge EPA to redouble its work to control nitrogen and phosphorus pollution generally and to develop numeric nitrogen and phosphorus standards for states and tribes that fail to do so.

Sincerely,

Kris Sigford
Minnesota Center for
Environmental Advocacy

Albert Ettinger
Counsel for the
Mississippi River Collaborative

On behalf of:
Environmental Law & Policy Center, Chicago, IL
Gulf Restoration Network, New Orleans, LA
Iowa Environmental Council, Des Moines, Iowa
Kentucky Waterways Alliance, Louisville, KY
Minnesota Center for Environmental Advocacy, St. Paul, MN
Missouri Coalition for the Environment, St. Louis, MO
Natural Resources Defense Council Midwest Office, Chicago, IL
Prairie Rivers Network, Champaign, IL
Tennessee Clean Water Network, Knoxville, TN

Attachments
Petition for Rulemaking Under the Clean Water Act - Numeric Water Quality Standards for Nitrogen and Phosphorus and TMDLS for the Mississippi River and the Gulf of Mexico, June 30, 2008

Memorandum, Nutrient Pollution and Numeric Water Quality Standards, Benjamin H. Grumbles

An Urgent Call to Action - Report of the State-EPA Nutrient Innovation Task Group, August 2009

Letter of Kris Sigford to Administrator Lisa M. Jackson, March 31, 2009

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FLORIDA TODAY (Brevard County, Florida)

December 15, 2010 Wednesday
Online Edition

Stop the pollution

BYLINE: By, FLORIDA TODAY EDITORIAL

SECTION: EDITORIAL; Pg. A14

LENGTH: 743 words

FLORIDA TODAY EDITORIAL

The waters of the Indian River Lagoon just got dirtier, threatening marine life and the economic benefits the estuary brings to the Space Coast.

The waters of the St. Johns River just got dirtier, threatening the drinking water supplies that are critical to Brevard County and Central Florida's future.

The coastal waters of the Atlantic Ocean and Gulf of Mexico just got dirtier, threatening the lure that attracts tens of millions of tourists to Florida annually.

Who's to blame?

Florida's top Republican lawmakers - and the polluting industries backing them - who continue fighting the implementation of clean-water rules the U.S. Environmental Protection Agency had ordered into place.

Their newest move came last week when Attorney General Bill McCollum, with the support of Gov.-elect Rick Scott and Attorney General-elect Pam Bondi, filed suit in federal court to block the standards.

The situation dates to 1998, when the EPA told Florida it was violating the Clean Water Act and needed to toughen measures to stop the toxic mix of agricultural, industrial and municipal pollutants entering state waters.

A menacing tide

A tide so menacing the state Department of Environmental Protection admitted in 2008 that nutrients had tainted 1,000 miles of rivers, 350,000 acres of lakes and 900 square miles of estuaries.

However, the state dragged its feet and missed a 2004 deadline to put the rules in place. That caused environmental groups to file a winning lawsuit against the EPA in 2008 that stipulated the agency step in.

As a result, the EPA finally released standards for lakes, rivers and springs last month after repeated meetings with state officials and making concessions. It will do the same for coastal waters in November 2011.

"These rules will give us cleaner water that will help stimulate the economy with more tourism, more boating, more recreation and create more jobs," says Jim Egan, director of the Palm Bay-based Marine Resources Council that tracks pollution levels in the Indian River Lagoon.

"These are good laws. They're not laws to protect a snail someplace. They would provide clean water and healthier water and more profitable economic conditions for the people of Florida."

The arguments opponents are making - that the rules are arbitrary, lack scientific support and would be too costly to implement - are false.

The standards are based on solid scientific research that 13 other states have used to adopt similar rules of their own. The EPA even used state-produced data in composing the new restraints.

Meanwhile, the EPA estimates cleanup costs between $135 million and $206 million annually. That's far below the billions claimed in a report written by an industry organization that includes some of the state's worst polluters.

If detractors were really worried about cost, they'd focus on the steep price Florida is paying for pollution.

A single algae bloom or red tide along the Atlantic or Gulf coasts hammers the tourism industry, shutting down beaches, leaving hotel rooms empty and damaging commercial and recreational fishing.

It also can trigger respiratory and other health problems in humans, as evidenced when a red tide struck the Brevard coast in 2008.

In the Indian River Lagoon alone, the alarming rise in illnesses striking marine life - including cancer and other diseases in dolphins - speaks to public health threats and diminished waterfront property values unless water quality improves.

Irreplaceable resource

And with it the $3.7 billion in economic impact the lagoon provides to the five counties that hug its shores, with more than $1.2 billion of the money staying in Brevard in fishing, boating and other activities.

The St. Johns River, the linchpin for drinking water supplies in East-Central Florida, is no less embattled with fertilizers, pesticides and metals from agriculture and urban stormwater runoff choking its flow and killing fish.

"If we continue to disregard these kind of rules, we're going to continue destroying the river," says Leroy Wright of Cocoa, who has battled for 30 years to clean up the waterway as founder and former president of SAVE the St. Johns.

State officials have had a dozen years to do the right thing and protect Florida's citizens, environment and economy on this issue. Instead, they have done everything possible to sabotage the process.

It's time for that shameful record to end and for the state's irreplacable waters to become cleaner, not dirtier.

LOAD-DATE: December 16, 2010

LANGUAGE: ENGLISH

PUBLICATION-TYPE: Newspaper

Stop the pollution FLORIDA TODAY (Brevard County, Florida) December 15, 2010
Wednesday

JOURNAL-CODE: brv

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Orlando Sentinel (Florida)

July 26, 2011 Tuesday
FINAL

Protect Florida's water
New federal regulations aren't the enemy; the lack of concern is.

BYLINE: Copper

SECTION: EDITORIAL; FLORIDA; What we think; Pg. A10

LENGTH: 590 words

Last year's hysterical reaction from opponents of tougher federal clean-water rules was, unfortunately, only the beginning.

Since the Associated Industries of Florida's Barney Bishop hammered "radical left-wingers" for daring to impose new regulations that would strap businesses, we've seen a lawsuit from Florida Attorney General Pam Bondi and Agriculture Commissioner Adam Putnam.

The pair sued those awful left-wingers running the Environmental Protection Agency for imposing what will be new limits on how much phosphorus and nitrogen can get into waterways from sewage plants, industry and other sources.

Central Florida's John Mica got into the act, too, introducing legislation in Congress that would blunt the EPA's ability to toughen Florida's ineffective water-pollution limits. The EPA's "almost unprecedented power grab" would create a "regulatory nightmare," Mica gasped on the floor of the U.S. House.

Central Florida's Sandy Adams injected her trademark hyperbole. The congresswoman tied the EPA's coming rules to clean Florida's waterways to an imagined plot by President Obama to undermine anti-pollution efforts. And her office said the new EPA rules "would effectively kill job creation throughout Florida."

Fortunately, Mica's bill won't make it to a vote in the Senate, which appreciates that the EPA should have the ability to draft and enforce rules making states comply with the federal Clean Water Act.

And, fortunately, the nonprofit National Research Council, which is holding meetings this week in Orlando, is continuing its months-long, deliberate study of what kind of financial burden the EPA's tougher water standards would truly impose on the state.

Make no mistake, Florida needs these new standards. A near-dead Lake Apopka, a chronically sick St. Johns River and the region's many algae-bloom-filled springs cry out for them. And with the NRC scientists examining the cost of making improvements to sewage plants, stormwater systems and septic systems, we expect they'll show that the financial burden from the standards will be significantly less than the $1,000 per year per sewage customer that opponents contend. The EPA's own estimate: $11 per resident.

If the arguments against the EPA's tougher nutrient standards sound familiar, that's because they've been used over and over again by reactionary lawmakers to eviscerate sensible regulations. The anti-environment gang in Tallahassee killed state growth laws they said killed jobs. What nonsense.

Washington lawmakers dropped efforts at meaningful climate-change legislation, and this month even tried to repeal sensible regulations designed to curb the use of wasteful light bulbs.

They did so saying these regulations stifled the ability of businesses to grow. Or cost businesses too much. Or would burden the public because consumers will get saddled with the costs.

Regulations frequently carry costs. But the cost of doing nothing can be greater. The state's lax water rules have allowed pollutants to choke Florida's waterways, lower property values and threaten the state's ability to draw tourists.

Opponents of the new EPA water rules also need to turn down their rhetoric if only for this reason: The EPA's new rules aren't one size fits all. The agency will let businesses and communities propose alternative standards if they can demonstrate that those alternatives would effectively protect the water.

The EPA wants Florida to clean its waterways without submerging its businesses. That's something anyone who calls Florida home also should want.

LOAD-DATE: July 26, 2011

LANGUAGE: ENGLISH

DOCUMENT-TYPE: EDITORIAL

PUBLICATION-TYPE: Newspaper

St. Petersburg Times
tampabay
St. Petersburg Times (Florida)

May 21, 2011 Saturday
4 State / Suncoast Edition

OBSTRUCTING THE PATH TO CLEANER WATER

SECTION: NATIONAL; TIMES EDITORIALS; Pg. 14A

LENGTH: 501 words

Florida continues to jeopardize its environment, tourism and public health by fighting the federal government over new clean water rules. Fortunately, state lawmakers did not pass legislation that would have barred the state from enforcing the rules, which are designed to curb pollution in lakes, rivers and estuaries. But that is small consolation; the state's Republican leaders are continuing a lawsuit challenging the Environmental Protection Agency's authority and the scientific basis for moving ahead. Only a strong mandate by the EPA will protect the state's resources.

Florida has dawdled long enough in addressing pollution that has tainted about 2,000 miles of the state's rivers and streams, 380,000 acres of its lakes and 569 square miles of its coastal areas. It is politically convenient for Florida Republicans to blame Democrats in Washington for the standoff, when the state spent years fiddling with new requirements. The reality is the federal government also dragged its feet as runoff from farms, utilities and sewer plants damaged the state's water bodies, endangering tourism, the environment, public health and property values.

If anything, the EPA should have acted long ago. The agency told the states in 1998 to limit nutrient pollution in surface waters by 2004 or it would do the job. But 2004 came and went. Environmental groups sued in 2008, calling on the EPA to enforce the antipollution standards under the Clean Water Act. The agency settled the case in 2009 under the stipulation that it would draft the new rules for Florida. The standards were 10 years in the making, put in motion under then-President George W. Bush and crafted in concert with two Republican governors of Florida. The state is hardly being blindsided by a big-footed federal bureaucracy waging a liberal agenda.

That hasn't stopped leading Republicans, the big business lobby and large-scale polluters from spreading disinformation. Opponents maintain the new standards will cost the state (and ultimately consumers) billions of dollars. But that figure is based on the fiction that Florida will need to use expensive processes such as reverse-osmosis to meet the new standards - even though the EPA has made clear time and again that reverse-osmosis is off the table. EPA estimates the rules will affect only a fraction of farms and industrial operations. And the agency has postponed enforcement of the rules until 2012 at the earliest to work with the state and polluters on loopholes that could water down the standards even further.

State officials have contrived a controversy to run out the clock. Much of the data the EPA has used comes from the state's own environmental agency. It is time the federal government moved ahead. Allowing more sewage, fertilizer and other pollution into the state's waterways only harms public health and the economy and makes the cleanup more expensive. Somebody has to protect Floridians from the indifference to the environment and clean water in Tallahassee.

LOAD-DATE: May 24, 2011

LANGUAGE: ENGLISH

DOCUMENT-TYPE: EDITORIAL

PUBLICATION-TYPE: Newspaper

STATE OF ALABAMA
DEPARTMENT OF AGRICULTURE AND INDUSTRIES
1445 Federal Drive • Montgomery, Alabama 36107-1123

John McMillan
Commissioner

October 3, 2011

Senator Jeff Sessions
Ranking Member, Subcommittee on Water & Wildlife
U.S. Senate
326 Senate Russell Building
Washington DC 20510

Dear Senator Sessions:

Alabama currently has regulations and partnerships in place to work with producers to minimize pollutants from entering rivers and streams. The Alabama Department of Agriculture and Industries, Alabama Cooperative Extension System, Alabama Farmers Federation, Auburn University, Alabama Department of Environmental Management (ADEM), Alabama State Soil and Water Conservation Committee, Soil and Water Conservation Districts, and the Natural Resources Conservation Service work closely with farmers and ranchers to effectively manage animal waste, not only to keep it out of America's rivers and streams, but also to turn it into a useful commodity.

The partnership works with private landowners to plan and implement best management practices as a mechanism to meet Federal, State, and local water quality requirements for agricultural and silvicultural lands. Practices are installed according to NRCS technical standards and are implemented through voluntary conservation efforts. The following procedures are in place to assist producers.

- ADEM requires concentrated animal feeding operations (CAFOs) to have a Comprehensive Nutrient Management Plan (CNMP) that meets or exceeds NRCS standards. The CNMP addresses natural resource concerns dealing with soil erosion, manure, and organic by-products and their potential impacts on water quality. It is developed to assist operators in meeting all applicable local, tribal, State, and Federal water quality goals or regulations. CAFO's are inspected annually by qualified credentialed professionals to ensure compliance with the plans.

- Certified Technical Service Providers (TSP's) are available to develop Conservation Activity Plans (CAPs) for CNMPs. CAPs are specialized, in-depth plans that address specific resources and can be used to improve management of an operation.

- Nitrogen and phosphorus are the primary nutrients that contribute to agricultural nonpoint source pollution. NRCS' Nutrient Management Practice Standard minimizes agricultural nonpoint source pollution of surface and ground water resources through managing nutrient application rates, placement, and timing. In addition, buffers and filter strips are used to trap nutrients and protect water quality. Recordkeeping systems are in place on the farm to monitor nutrient applications.

Adding additional regulations or changes to Alabama's best management practices would detrimentally affect the state's economy and farmers. If problems do occur, we feel they could best be addressed through University research and science-based technology.

Sincerely,

John McMillan

The
Fertilizer Institute
Nourish, Replenish, Grow

October 3, 2011

The Honorable Benjamin L. Cardin
Chairman, Subcommittee on Water and Wildlife
Committee on Environment and Public Works
United States Senate
Washington, DC 20510

The Honorable Jeff Sessions
Ranking Member, Subcommittee on Water and Wildlife
Committee on Environment and Public Works
United States Senate
Washington, DC 20510

Dear Chairman Cardin and Ranking Member Sessions:

The Fertilizer Institute (TFI) is the leading voice of the fertilizer industry, representing the public policy, communication and statistical needs of producers, manufacturers, retailers and transporters of fertilizer. The Institute's members play a key role in producing and distributing vital crop nutrients, such as nitrogen, phosphorus and potassium, which are used to replenish soils throughout the United States that in turn produce healthy and abundant supplies of food, fiber and fuel. While the fertilizer industry is known for its positive contributions in agriculture and food production, awareness of the industry has also increased as a result of issues involving excess nutrients in the environment.

TFI, on behalf of its members, is pleased with the opportunity that today's hearing presents for our industry to define its continued commitment to environmental stewardship. At the heart of that commitment is what is known as 4R nutrient stewardship, a framework to achieve cropping system goals, such as increased production, increased farmer profitability, enhanced environmental protection and improved sustainability. To achieve those goals, the 4R concept incorporates the:

- **Right fertilizer source** at the
- **Right rate**, at the
- **Right time** and in the
- **Right place**.

Although the 4R nutrient stewardship brand is relatively new, the practices that comprise the system are not. According to the Association of American Plant Food Control Officials, since 1987, the Chesapeake Bay Area states, which include Delaware, Maryland, New York, Pennsylvania, Virginia and West Virginia, have reduced fertilizer nutrient consumption by 32 percent. Despite these positive gains, the industry recognizes that further improvement is both possible and necessary.

To that end, TFI has begun to implement its 4R nutrient stewardship strategic plan that is aimed at increasing awareness of 4R nutrient stewardship among agricultural stakeholders. Efforts to create educational tools and resources that will facilitate greater adoption of the 4Rs by agricultural producers

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www.tfi.org

are already underway. Additionally, TFI has begun work to develop measurement systems that will eventually be used to demonstrate the environmental improvements associated with implementation of 4R nutrient stewardship.

Enclosed with this letter is a more detailed overview of the 4R nutrient stewardship concept, as well as several informational posters which were originally presented by TFI at the Soil Water Conservation Society's annual conference which took place in Washington, D.C., on July 11. Additional information regarding the 4Rs is also available at www.nutrientstewardship.com.

TFI wishes to thank the U.S. Senate Committee on Environment and Public Works Subcommittee on Water and Wildlife for the opportunity to submit these comments for the record in regards to its hearing on "Nutrient Pollution: An Overview of Nutrient Reduction Approaches." If you are interested in discussing this letter or the materials included along with it, please contact me by telephone at (202) 515-2700 or via e-mail at fwest@tfi.org.

Sincerely,

Ford B West

Ford B. West
President

nutrient stewardship

4R NUTRIENT STEWARDSHIP

4R nutrient stewardship provides a framework to achieve cropping system goals – increased production, increased farmer profitability, and enhanced environmental protection. To achieve those goals the 4Rs utilize fertilizer best management practices that address the Right Nutrient Source, at the Right Rate, the Right Time, and in the Right Place. The four "rights" are necessary for sustainable plant nutrition management. The assessment of any planned nutrient management practice must consider the economic, social, and environmental effects to determine whether or not it is a "right" practice for that system.

4R Universal Scientific Principles

The 4R nutrient stewardship principles are the same globally, but how they are used locally varies depending on field and site specific characteristics such as soil, cropping system, management techniques and climate.

RIGHT SOURCE

Ensure a balanced supply of essential nutrients, considering both naturally available sources and the characteristics of specific products in plant available forms. Specifically – consider nutrient supply in plant available forms, ensure nutrient suits soil properties, and recognize the synergisms among elements.

RIGHT RATE

Assess and make decisions based on soil nutrient supply and plant demand. Specifically – appropriately assess soil nutrient supply (including those from organic sources and existing soil levels), assess plant demand, and predict fertilizer use efficiency.

RIGHT TIME

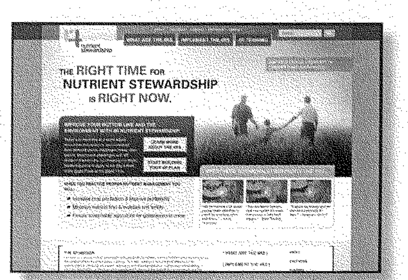
Assess and make decisions based on the dynamics of crop uptake, soil supply, nutrient loss risks, and field operation logistics. Specifically – assess the timing of crop uptake, assess the dynamics of the soil's nutrient supply, recognize weather factors, and consider logistics.

RIGHT PLACE

Address root-soil dynamics and nutrient movement, and manage spatial variability within the field to meet site-specific crop needs and limit potential losses from the field. Specifically – recognize root – soil dynamics, manage spatial variability issues, consider the tillage system, and limit potential off-field transport.

To help identify opportunities to improve fertilizer efficiency and prevent nutrient movement from each field, ask:

Was the **RIGHT FERTILIZER SOURCE** *given to the crop at the* **RIGHT RATE, RIGHT TIME,** *and in the* **RIGHT PLACE?**



The new www.nutrientstewardship.com website promotes the 4R philosophy, an innovative and scienced-based approach that offers enhanced environmental protection, increased production, increased farmer profitability, and improved sustainability.

Learn more about 4R nutrient stewardship at www.nutrientstewardship.com.

The United States Department of Agriculture Natural Resource Conservation Service (USDA NRCS) has been undertaking Conservation Effectiveness Assessment Program (CEAP) studies in major watersheds throughout the United States. Key findings indicate **that suites of best management practices work better than single practices**, and that there is a need to **increase the complete and consistent use of nutrient management**, defined as using strategies that address proper **rate, form, timing, and placement**.

RIGHT SOURCE – RIGHT RATE – RIGHT TIME – RIGHT PLACE

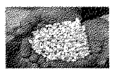
4R nutrient stewardship

The Right Time for Nutrient Stewardship is Right Now

The Fertilizer Institute
Nourish, Replenish, Grow

Agriculture is Facing Challenges

Population Pressures



According to the United Nations, the global population will increase by more than two billion people in the next 40 years, and reports have indicated that food production needs to double by 2050.

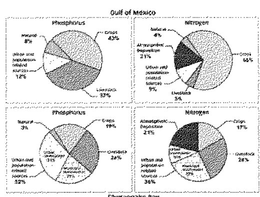
- Increased food production will be achieved by intensified crop production and not by an expanded arable land base
- Genetic and biotech seed industries have predicted yield increases of three to four percent per year
- To optimize the yields of advance seeds, fertilizer inputs must be optimized to provide the greatest potential for success.

Policy Pressures

Pressure to limit the use of fertilizers is increasing. Legislative, regulatory and non-government activities , including legal action pertaining to nutrients in the environment, are taking place on national, state and local levels:

- EPA Assessments:
  - 14,000 nutrient related surface water impairment listings in 49 states
  - Over 47 % of streams contain medium to high levels of N and P
- USDA – NRCS
  - Conservation Effectiveness Assessment Program (CEAP) indicates 60-80% of cropland needs additional nutrient management to reduce N and P loss
  - Environmental groups and federal government applying pressure on states to develop additional regulations and nutrient reduction strategies

N and P Contributors to the Chesapeake Bay and the Mississippi River Basin



What are the 4Rs?

4R Nutrient Stewardship

The 4Rs provide a framework to achieve cropping system goals – increased production, increased farmer profitability, enhanced environmental protection and improved sustainability. To achieve those goals, the 4Rs incorporate the:

RIGHT FERTILIZER SOURCE *at the* RIGHT RATE, *at the* RIGHT TIME *and in the* RIGHT PLACE.

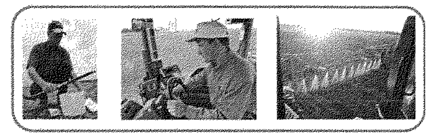
- The **Right Source** utilizes nutrients that are in – or easily converted to – compounds best used by target crops.
- The **Right Rate** utilizes nutrient applications that match supply with crop requirements.
- The **Right Time** utilizes practices to ensure nutrients are available when crop demand is high.
- The **Right Place** utilizes practices to locate nutrients where they can be effectively accessed by the crop.

NRCS and the 4Rs

CEAP Watershed Studies

The CEAP studies use a combination of surveys and modeling to determine the effects of implemented conservation practices. Reports have been released for the Upper Mississippi River Basin and the Chesapeake Bay using data from 2003 - 2006.

- A key finding shows the need to increase complete and consistent use of nutrient management, defined as using strategies that address proper rate, form, timing, and method of application
- Specifically, the model showed that suites of practices which include soil erosion control and nutrient management are required to simultaneously address soil erosion and nutrient loss.



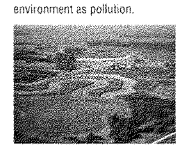
Answering the Challenges

Improved Agricultural Productivity

- Optimizing nutrient management minimizes risks associated with fluctuations in prices of fertilizer and other inputs.
- Higher crop yields are well documented with better crop and soil management.
- Improved fertilizer efficiency increases the quantity produced per acre for each unit of nutrient applied, without sacrificing yield.

Minimize Impact to the Environment

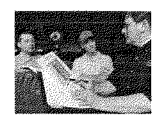
- Nutrient stewardship contributes to the preservation of natural ecosystems by growing more on less land.
- Retaining nutrients within a field's boundaries and in the crop rooting zone greatly reduces the amount that is not utilized by plants and thereby escapes in the environment as pollution.



Other agronomic and conservation practices such as no-till and the use of cover crops, play a valuable role in supporting 4R nutrient stewardship. Fertilizer BMPs are most effective when applied with other agronomic and conservation practices.

What Can You Do?

- Educate yourself
- Consider ways to expand your 4R practices
- Spread the word



THE *RIGHT TIME* FOR *NUTRIENT STEWARDSHIP* IS *RIGHT NOW*

RIGHT SOURCE – RIGHT RATE – RIGHT TIME – RIGHT PLACE

nutrient stewardship

Implementing 4R Nutrient Stewardship on the Farm

IPNI International Plant Nutrition Institute

Implementing the 4Rs

Agriculture is being challenged to maintain profitable farm economics, while meeting the increased product demands of a growing population, and responding to increased scrutiny of land an d resource management. Agricultural sustainability addresses economic, environmental , and social goals . The 4Rs imply there are four aspects to every fertilizer application and it provides a framework to assess whether a given crop has access to the necessary nutrients. To help identify opportunities to improve fertilizer efficiency and prevent nutrient movement from each field, ask:

Was the **RIGHT FERTILIZER SOURCE** *given to the crop at the* **RIGHT RATE, RIGHT TIME,** *and in the* **RIGHT PLACE?**

4R Principles

The principles are the same globally, but how they are used locally varies depending on field and site specific characteristics.

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Ensure a balanced supply of essential nutrients. Specifically -consider nutrient supply in plant available forms, ensure nutrient suits soil properties, and recognize the synergisms among elements.

RIGHT RATE
Assess and make decisions based on soil nutrient supply and plant demand. Specifically – appropriately assess soil nutrient supply (including those from organic sources and existing soil levels), assess plant demand, and predict fertilizer use efficiency.

RIGHT TIME
Assess and make decisions based on the dynamics of crop uptake, soil supply, nutrient loss risks, and field operation logistics. Specifically – assess the timing of crop uptake, assess the dynamics of the soil's nutrient supply, recognize weather factors, and consider logistics.

RIGHT PLACE
Address root-soil dynamics and nutrient movement, and manage spatial variability within the field to meet site-specific crop needs and limit potential losses from the field. Specifically – recognize root – soil dynamics, manage spatial variability issues, consider the tillage system, and limit potential off-field transport.

Steps to Implementing 4Rs on the Farm

1. Identify economic, social and environmental goals that cropping system objectives should address specific to each field and operation.
2. Select BMPs that are specific to the soil, climate, cropping system and goals identified by the grower.
3. Integrate BMPs for all goals an d adjust as needed.
4. Document the 4R nutrient stewardship plan.

Example Goals

Economic Goals

- Improve net farm income
- Contribute to improved regional economic development

Social Goals

- Improve the quality of farm family housing, diet, and education
- Improve the productivity of farm labor by appropriate use of emerging technologies that increase efficiencies of field operations and reduce costs per unit of crop harvested
- Improve assess to sources of information to assist in farm management decision making

Environmental Goals

- Maintain or reduce unwanted losses of nutrient s to the environment:
  - Reduce soil erosion of nutrient containing soil particles;
  - Reduce volatile ammonia (NH3) emissions;
  - Reduce nitrification/de-nitrification losses of nitrous oxide (N2O) and di-nitrogen (N2).
- Reduce energy use per harvested unit of farm production.
- Improve recycling of crop nutrien5s from crop residues and livestock manures.

Example BMPs

Right Source

- Select appropriate fertilizer and on-farm nutrient sources for the cropping system including consideration for commercial fertilizer form, enhanced efficiency fertilizer products, manure or biosolids.

Right Rate

- Utilize grid or zone soil testing and rate recommendations
- Use nutrient budgets to plan management and application schemes (including yield goal analysis, crop removal balance and plant tissue analysis)
- Utilize variable rate application technologies to address spatial variability
- Use in-season methods to make in season decisions such as leaf color charts, chlorophyll meters, or optical sensors.

Right Time

- Follow recommended times for nutrient applications
- When necessary utilize enhanced efficiency fertilizers for controlled nutrient release and urease or nitrification inhibition
- Utilize split applications to improve crop nutrient uptake.

Right Place

- Utilize application methods that limit nutrient losses
- Incorporate fertilizers
- Adjust applications to avoid unnecessary applications to non-crop areas
- Couple applications with appropriate soil conservation practices
- Utilize controlled drain management in tile drained fields.

THE *RIGHT TIME* FOR *NUTRIENT STEWARDSHIP* IS *RIGHT NOW*

RIGHT SOURCE – RIGHT RATE – RIGHT TIME – RIGHT PLACE

nutrient stewardship

4R Materials and Educational Tools

The Fertilizer Institute
Nourish, Replenish, Grow

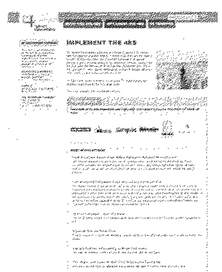
www.nutrientstewardship.com

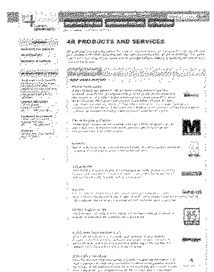
Help agriculture speak with one voice when it comes to nutrient stewardship.

The 4R nutrient stewardship initiative creates a brand for the 4R concept. The fertilizer industry and agricultural stakeholders throughout the U.S. must speak with a common voice to increase awareness and comprehension of fertilizer best management practices.

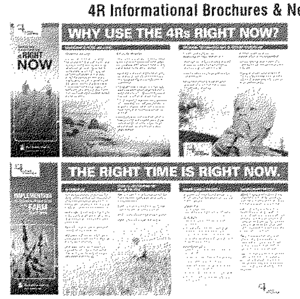
Fertilizer is a component of sustainable crop production systems, and the fertilizer industry recognizes the need to efficiently utilize these nutrients. The www.nutrientstewardship.com website provides science-based information for stakeholders to utilize for education, advocacy, and implementation of crop nutrient stewardship. It provides information on fertilizer best management practices that benefit the environment and the producer's bottom line. The website provides:

- Articles regarding fertilizer best management practices
- Information about partner products and service that supplement 4R
- Information about 4R supporters
- Video testimonial from producers and service providers utilizing the 4Rs
- Access to 4R materials for distribution





4R Informational Brochures & Newsletters



The 4R informational brochures are available for download on the 4R website (www.nutrientstewardship.com). 4R partners and supporters have the opportunity to co-brand the brochures to further communicate with their clientele and members.

The *Right Time for Nutrient Stewardship is Right Now* brochure explains the 4R concept and discusses the reasons why it is important to spread knowledge of the 4Rs and promote implementation of the science based system right now.

Implementing 4R Nutrient Stewardship on the Farm offers specific information regarding the agronomic and economic objectives that growers may establish and achieve through 4R adoption.

Complete the "Contact Us" form on the website to sign up for the 4R nutrient stewardship quarterly newsletter to receive updates to the website's articles and events, as well as updates to the 4R initative.

Current Projects Leading to Additional Tools

NRCS 590 Nutrient Management Standard Educational Modules

- Project Partners – The Fertilizer Institute, Natural Resources Conservation Service, International Plant Nutrition Institute, Iowa State University
- Project will:
  - Develop educational media for service providers
  - Organize and build upon existing supporting resources
  - Develop economic case studies
  - Develop educational brochures and fact sheets targeted at producers
- Educational curriculum will serve as a multiplier of nutrient stewardship efforts.
- Developed materials will be accessible through an online learning module.
- Project funded by NRCS with matching funds from The Fertilizer Insitute

4Rs for N_2O Emission Reductions and Carbon Credit Sales

- Project Partners - The Fertilizer Institute, Camco, ClimateCHECK, Climate Trust, the International Plant Nutrition Institute, USDA's National Laboratory on Agriculture and the Environment, the National Corn Growers Association, Michigan State University, and Colorado State University
- Develop and implement a program to recruit and enroll producers and to provide them with expert advice to implement, monitor, and track fertilizer BMP efforts resulting in monetization of carbon offsets.
- Effort will also evaluate and road test the Alberta Nitrous Oxide Emissions Protocol (NERP), the American Carbon Registry protocol (ACR), and the Verified Carbon Standard protocol (VCS).
  - Project funds include protocol modification (as needed) for their use in Iowa and Illinois with corn and soybean cropping systems.
  - A meta-data analysis (extensive literature review) will be utilized to help evaluate the effect of implemented fertilizer BMPs on nitrous oxide emission reductions.
- Anticipate enrolling 100 producers in the program to implement nitrogen BMPs to create, quantify, and monetize carbon credits.
- Project funded by NRCS with matching funds from project partners.

THE *RIGHT TIME* FOR *NUTRIENT STEWARDSHIP* IS *RIGHT NOW*

4R nutrient stewardship

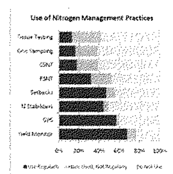
A 4R Nutrient Stewardship Plan in Action

DELAWARE MARYLAND

Opportunities for Increased Adoption of 4R

4Rs in Upper Chester River Watershed, Maryland

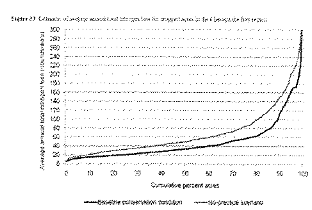
- USDA-led effort targeting resources to increase conservation adoption by seeking to reach 100 percent of residents in the watershed.
- Maryland Department of Agriculture provided funds to perform a farm assessment in the watershed; 87 percent of the agricultural land is represented in the results.
- The survey captures the current implementation of 4Rs nutrient use efficiency management tools.



This table shows common N management practices and their common use among farmers in the watershed. Most farms (56 percent) use at least two of these practices. 25 percent of the farms use four or more of these practices regularly. Source – Upper Chester River Showcase Watershed Project Farm Assessment Report

Opportunity for Increased 4Rs Adoption – NRCS CEAP

- Assessment of the Effects of Conservation Practices on Cultivated Cropland in the Chesapeake Bay Region (USDA NRCS, February 2011)
- Report indicates - "The greatest conservation need in the region is complete and consistent use of nutrient management—appropriate rate, form, timing, and method of application."



Acres with the highest nitrogen losses have the highest inherent vulnerability combined with inadequate nutrient management and runoff controls. About 59 percent of cropped acres lose less than 40 lbs/ac/yr, while 10 percent lose more than 100 lbs/ac/yr. Source – USDA NRCS Chesapeake Bay CEAP Report.

Pathways for 4R Implementation

Targeting 4Rs for Water Quality Improvements

- A report from the Harry Hughes Center for Agro-Ecology (2008) indicated that both geographically and programmatically targeted funding is necessary.
- Geographic locations should be identified (based on soil type, slope, distance to streams, cropping systems, et al.) that contribute the greatest nitrogen, phosphorus, and sediment loads ; then suites of practices should be strategically implemented to maximize reductions.
- MD NRCS, with their Partners:
  - Identify the highest agriculturally impaired watershed segments with greatest nutrient/sediment loads to the tidal Chesapeake Bay;
  - Identify farms with the highest potential of resource impact and eligibility for Farm Bill funding to implement priority nutrient/sediment-reducing practices;
  - Work with Partners to outreach and provide technical assistance to these individual producers to implement cost-effective practices that are most effective at reducing nutrients and/or sediment. (Nutrient Subcommittee, MD NRCS State Technical Committee, June 19, 2009)

Maryland NRCS Offer a Tiered 590 Nutrient Management Standard

Soil/Tissue Sampling

- Precision soil sampling or "smart sampling"
- Tissue Testing
- Soil N (Nitrate) Test
- Chlorophyll Meter Test
- PSNT if manure is used or field has high organic soils

Nutrient Application Timing

- Injection of side dress application of nitrogen on Corn
- Band Applications of Phosphorus
- Split Applications of Nitrogen – Small grain

Forms of Nitrogen Applied

- Utilize Slow or Controlled Release Nitrogen
- Use of Urease Inhibitor

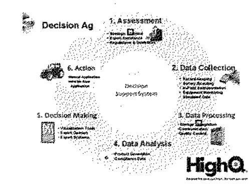
Enhanced Nutrient Management – Decision Agriculture

Producer provided documentation of implementing Decision Agriculture nutrient management system techniques which include: management tool maps (yield maps, planting maps, bar charts) crop productivity charts and field input data (application of nutrients, pesticides, irrigation, crop records).

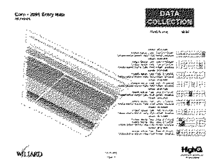
4R Implementation

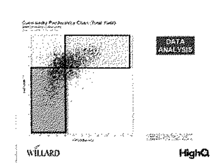
Decision Support System for 4Rs

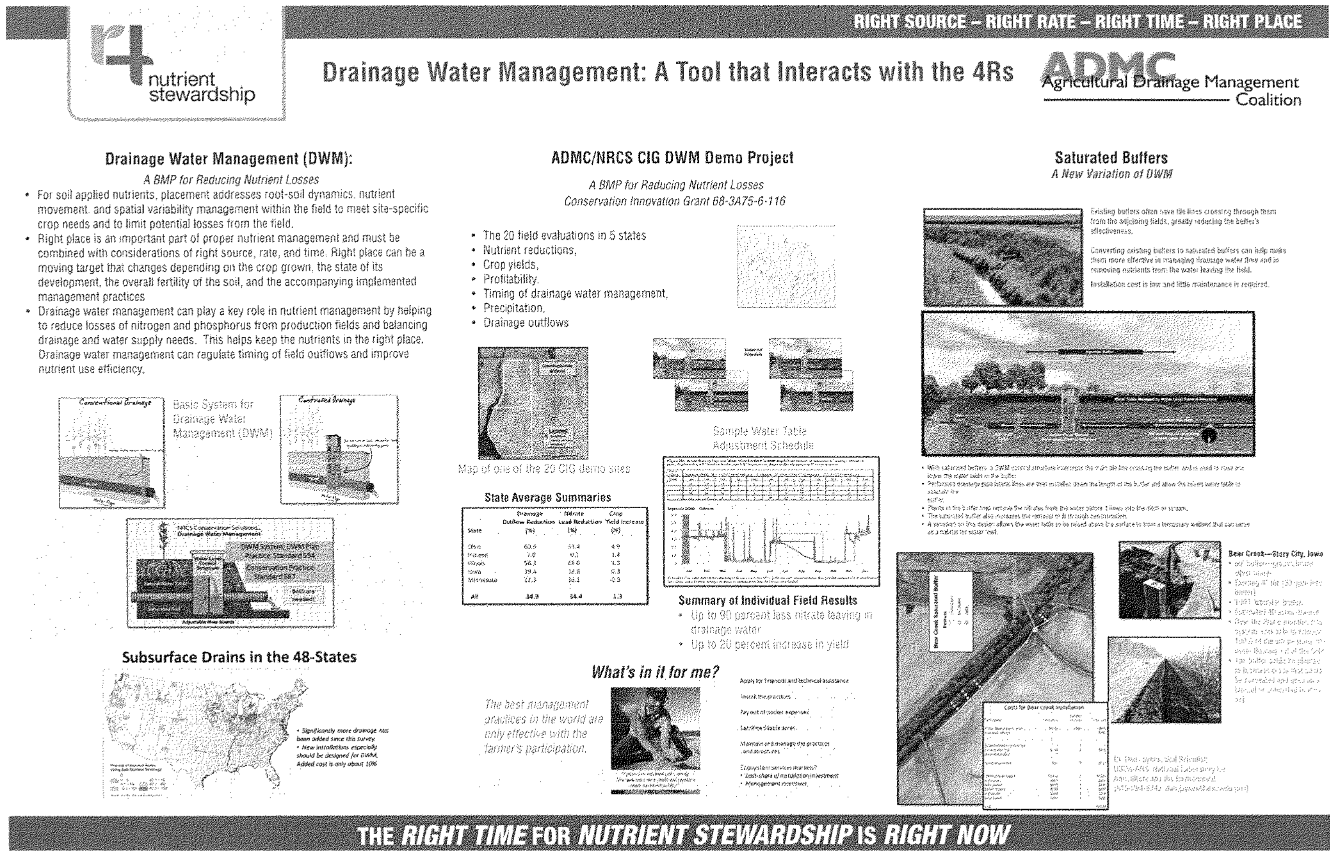
- MD NRCS defined "Enhanced Nutrient Management - Decision Support System"
  - utilize a GPS and yield monitoring system to collect field-specific crop data, and a software/record keeping system that analyzes that data. Utilize this analysis to adjust field inputs, which may include variable rate fertilizer, lime, and/or variable rate planting.
- Involves the development and use of an extensive record keeping system of crop management and yield data inputs using GPS technology to ensure the most efficient production is achieved.
- HighQ ™ Decision Support System offered by Willard Agri-Service to farmers in PA, MD, VA and DE meets this NRCS definition. The HighQ™ system equals:



Other retailers and agronomists offer programs with similar characteristics and services in other regions of the country. Retail associations and agronomic services can provide the level of detail and services necessary to implement the 4Rs/Enhanced Nutrient Management systems on the farm.






RIGHT SOURCE – RIGHT RATE – RIGHT TIME – RIGHT PLACE
nutrient stewardship
Drainage Water Management: A Tool that Interacts with the 4Rs
ADMC Agricultural Drainage Management Coalition
Drainage Water Management (DWM):
A BMP for Reducing Nutrient Losses
• For soil applied nutrients, placement addresses root-soil dynamics, nutrient movement, and spatial variability management within the field to meet site-specific crop needs and to limit potential losses from the field.
• Right place is an important part of proper nutrient management and must be combined with considerations of right source, rate, and time. Right place can be a moving target that changes depending on the crop grown, the state of its development, the overall fertility of the soil, and the accompanying implemented management practices.
• Drainage water management can play a key role in nutrient management by helping to reduce losses of nitrogen and phosphorus from production fields and balancing drainage and water supply needs. This helps keep the nutrients in the right place. Drainage water management can regulate timing of field outflows and improve nutrient use efficiency.
Conventional Drainage
Basic System for Drainage Water Management (DWM)
Controlled Drainage
Subsurface Drains in the 48-States
ADMC/NRCS CIG DWM Demo Project
A BMP for Reducing Nutrient Losses
Conservation Innovation Grant 68-3A75-6-116
• The 20 field evaluations in 5 states
• Nutrient reductions,
• Crop yields,
• Profitability,
• Timing of drainage water management,
• Precipitation,
• Drainage outflows
Map of one of the 20 CIG demo sites
Sample Water Table Adjustment Schedule
State Average Summaries
State | Drainage Outflow Reduction (%) | Nitrate Load Reduction (%) | Crop Yield Increase (%)
Ohio | 60.5 | 58.4 | 4.9
Indiana | 7.0 | 40.1 | 1.4
Illinois | 56.3 | 69.0 | 1.3
Iowa | 39.4 | 38.8 | 0.3
Minnesota | 22.3 | 36.1 | -0.3
All | 34.9 | 56.4 | 1.3
Summary of Individual Field Results
• Up to 90 percent less nitrate leaving in drainage water
• Up to 20 percent increase in yield
What's in it for me?
The best management practices in the world are only effective with the farmer's participation.
Saturated Buffers
A New Variation of DWM
Existing buffers often have tile lines crossing through them from the adjoining fields, greatly reducing the buffer's effectiveness.
Converting existing buffers to saturated buffers can help make them more effective in managing drainage water flow and in removing nutrients from the water leaving the field.
Installation cost is low and little maintenance is required.
Bear Creek—Story City, Iowa
Costs for Bear Creek installation
THE RIGHT TIME FOR NUTRIENT STEWARDSHIP IS RIGHT NOW

RIGHT SOURCE – RIGHT RATE – RIGHT TIME – RIGHT PLACE

4R nutrient stewardship

Spatial Variability of the Right Rate and How it Effects Timing and Placement

UNIVERSITY OF MARYLAND EXTENSION
Solutions in your community

Introduction

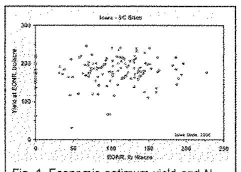


Fig. 1. Economic optimum yield and N requirement are unrelated.

University of Maryland Extension (UME) recommends 70 – 120 lbs-N ac-1 for winter wheat production. It is preferred that it be delivered in a split application with 0 – 40 lbs at planting and the remainder split into two spring applications. Similarly, UME recommends 1 lb-N ac-1 per bushel of expected yield for corn, with 20 – 40% of the N applied as starter and the remainder at side-dress after the V-4 stage. This formula does not consider soil N content, variations in soil N content or crop N requirement across the field, or seasonal variations in N requirement. While a sufficient quantity of N is critical for profitable grain production, appropriate application (amount, timing, and placement) of this N is critical for minimizing nitrate contamination of ground and surface waters and to prevent lodging in wheat. Thus, proper N fertilizer rates and application techniques are important factors in maximizing both grain yield and quality, and protecting the environment from excess N. Fundamentally, UME's approach is flawed because N requirement is not solely dependent on yield potential (Fig. 1) and is highly variable from year to year. Accurate assessments of N requirements would allow effective and environmentally sound fertilizer practices. However, due to the mobility of N in the soil and temporal and spatial variability accurate assessment of N availability and N requirement are difficult. A direct query of the plants themselves may be the answer.

Active Optical Sensors

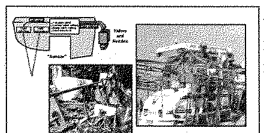


Fig. 2. GreenSeeker sensor schematic and photos mounted on sprayers.

Active optical sensors can be used to measure the vigor of a crop and can be used to show variability across a field. Active optical sensors have advantages over satellite or aerial imagery by providing real-time data, they can operate night or day, and they are not affected by cloud cover or fog. One such active optical sensor, the GreenSeeker© (Fig. 2), emits light in the red and near infrared wavelengths and calculates the normalized differential vegetative index (NDVI). Numerous algorithms have been developed to translate NDVI readings into N requirements at side-dress. These sensors have been proven to work very well across the USA and represent a major step forward in N management and variable rate application. Corn studies conducted by Virginia Tech showed that the same grain yields or slightly better could be achieved with 21% less N for corn and 10% less N for wheat using the GreenSeeker© along with their algorithm.

Fundamental Concepts

- Nitrogen requirement to achieve maximum yield for cereal grains is determined by N responsiveness and potential yield.
- Both yield potential and N responsiveness vary spatially and temporally.
- Yield potential and N responsiveness are independent of each other and independent of time.
- Soil type, climate, and previous management vary in space and time and influence yield potential and N responsiveness independently.
- The resolution at which we can vary N rate, both spatially and temporally, is limited; however, advantages in NUE can be achieved by addressing the spatial and temporal variation at the finest scale possible.
- Equipment capability in large part determines the scale at which we can address this variability (either spatial or temporal).
  - For example in dryland wheat or corn production the temporal scale at which we can address N needs is limited by equipment clearance and balancing the number of trips across a field with the economic return on the investment in multiple trips. Typically, self-propelled equipment is used to apply N once in-season for corn (V-4 stage) and twice for wheat (at greenup and Feekes 5-6) in the Mid-Atlantic.
  - The spatial resolution at which fertilizer N can be applied is almost totally dependent on equipment capabilities. Size of independent boom sections and response time of flow control are the dominant factors in determine the spatial resolution achievable.

Implementation

The Virginia Tech algorithms for corn and wheat have been shown effective at improving NUE. These algorithms use sensor and user inputs to generate a N prescription that can vary in real time as the equipment travels across the field.

User Inputs	Sensor Inputs
•Days from planting	•High N reference
•Maximum yield	•Low N reference
•N applied to-date	•Area currently in sensor view

Algorithm

The following equation uses sensor inputs to calculate predicted yield with added N (YPN) and without added N (YP0). The difference is the yield from added N, which is multiplied by the N content of the grain (PN). This gives the amount of N needed to maximize yield, which is then divided by the expected NUE.

IF

$$YP_N < Max\ Yield$$

Then

$$N\ Rate = \frac{(YP_N - YP_0) * P_N}{NUE} + (100 - N_{pre})$$

Else

$$N\ Rate = \frac{(MaxYield - YP_0) * P_N}{NUE} + (100 - N_{pre})$$

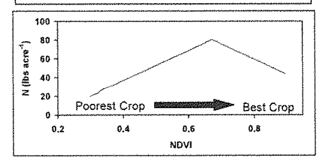


Fig. 3. General algorithm approach.

Conclusions

- In-season N fertilization with the Virginia Tech algorithm and active sensors allows the producer to address season to season variability and spatial variability.
- Fundamental to these advancements is the concept that yield potential and N responsiveness are independent variables that both play a role in determining crop N requirements. Furthermore, these variables do not display a consistent relationship across time and space.
- Sensor-based algorithms like Virginia Tech's prescribe N rate based on N responsiveness and yield potential. They do this site-specifically within the context of a given season, accounting for temporal and spatial variations and the independence of N responsiveness from yield potential.

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